

Missouri River Shallow Water Habitat Accounting Report – 2010

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The Missouri River Biological Opinion (BiOp) (UFWFS, 2000) and the Amended Biological Opinion (USFWS, 2003) set forth the definition of shallow water habitat as Missouri River flow depths less than 5 feet (1.5M) and velocities less than 2 fps (0.6 m/s) (USFWS, 2003, pg. 193). Subsequently, the definition of shallow water habitat was clarified in a letter from the USFWS to the USACE dated June 29, 2009, emphasizing the use of depth and velocity criteria as general guidelines and iterating the importance of depth and velocity diversity, increased productivity, and erosion and depositional processes. This analysis is based only on the general criteria of depths less than 5 feet (1.5M) and flow velocity less than 2 ft/sec (0.6 m/s) because other qualitative data are not yet available. An expanded monitoring effort including additional metrics based on the clarified definition will begin in 2011.

The SWH restoration goal as outlined in the BiOp is to achieve an average of 20-30 acres of shallow water per mile of river. The near term goals of the project are to reach 10% (2000 acres) of the SWH goal by 2005 and 30% (5,870 acres) by 2010. These targets have been setback by as much as 4 years as a result of the Yellowstone fish passage project as outlined in a letter from the USFWS to the USACE dated October 23, 2009.

Description of Methods and Process for 2010 accounting

Two counts of shallow water habitat were performed. The first count includes all SWH acres present regardless of the source or construction date. Extrapolation of HAMP data and GIS evaluations were used to estimate SWH distribution on the Missouri River. The second count includes constructed acres used to track progress toward the targets in the BiOp (see appendices A and B for detailed accounting methods).

I. Current SWH acreage distribution from Ponca to St. Louis

Distributions of SWH acres were estimated by dividing the Missouri River from Ponca to St. Louis into the five segments defined in the BiOp based on influences of large tributaries and current habitat (Table 1).

Table 1.- Estimates of shallow water habitat acreages currently present as determined by two methods and compared to base acres listed in BiOp.

River segment	Acres/mile (HAMP)	Acres/mile (GIS)	BiOP base acres
11 – Ponca to Sioux City	NA	5.6	2
12 - Sioux City to Platte R.	4.8	5.6	1.8
13 - Platte R. to Kansas River*	6.3	9.4	4.6
14 - Kansas River to Osage R.	17.8	17.1	4.6
15 – Osage R. to mouth	20.8	18.4	5

**Segment 13 includes separate estimates from Kansas City and Omaha USACE Districts. Numbers were weighted according to reach length within each District to attain an average count for the segment.*

II. Estimation of constructed shallow water habitat acres

For each type of project (i.e. chutes including revetment chutes, backwaters, and structure modifications including both modifications to dikes and revetments) SWH acreage estimates were based on pre and post field surveys, site assessments, and an estimate of future river dynamics. Minimum values are those occurring immediately following construction and anticipated future values are those expected once habitat changes have fully progressed (for example, once the River has widened to the extent allowed following bank notches). Acres of constructed SWH are reported in Table 2.

Table 2.- Acres of constructed shallow water habitat

	Current	Minimum	Anticipated future acres
Omaha District			
Chutes and revetment chutes	572	348	659
Backwaters	413	367	481
Main-channel modifications	312	421	840
Kansas City District			
Chutes and revetment chutes	331	171	450
Main-channel modifications	1815	1202	4799
Total	3443	2509	7229

III. General description of methods

Acres of constructed habitat from the Omaha District were calculated as follows: Current acreages were estimated using numerous data sources from limited extent surveys extrapolated to all constructed projects. Current acreage estimates for chute and backwater areas were derived from GIS measurements using the best available aerial photos at each site, generally between 2006 and 2009. Current main channel modifications were estimated by extrapolating best available data from the HAMP and GIS analyses. It should be noted that estimates for current main channel acreage are less than the minimum acreage previously estimated in the Omaha District. Minimum and anticipated future values were estimated prior to construction based on experience with similar projects. Acreages from the Kansas City District were calculated similarly with the following exceptions: Current acreage estimates for chutes and revetment chutes were calculated using 2009 and 2010 field surveys at selected sites and for remaining sites acreages were calculated assuming a width of 275 feet for chutes and double the construction width for revetment chutes. Current acres for main channel modifications were estimated based on analysis of past modification efforts. (see Appendices A and B for details).

It appears main channel acreage development is proceeding at a slower pace than projected. Future acreage accounting for main channel modifications should consider overall bend performance and further evaluate whether acreage estimates from extrapolations of past efforts remain accurate. Future monitoring will incorporate criteria specified in the clarified SWH definition to help evaluate quality of created habitats and provide needed information for adaptive management.

Appendix A

Omaha District Missouri River Shallow Water Habitat Report December 2010



Little Sioux Bend Dike Notching, Fall 2009

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Attachment A. Office Report, *Shallow Water Habitat Reconnaissance, Missouri River Chutes*, Omaha District, Aug 2009.

Attachment B. Omaha District Structure Modification Tabulation, Dec. 2010.

1 Introduction

This document provides an estimate of shallow water habitat acreage within the Omaha District and describes the methodology used to derive the estimate. Acreage estimates were performed using a variety of methods for the 2010 acreage update.

The Missouri River Biological Opinion (BiOp) (USFWS, 2000) and the Amended Biological Opinion (USFWS, 2003) set forth the definition of shallow water habitat (SWH). The parameters used to define SWH are Missouri River flow depths less than 5 feet (1.5 m) and velocities less than 2 fps (0.6 m/s) (USFWS, 2003, pg. 193). For the purposes of assessing habitat creation, the effective discharge is defined as the 50% exceedance discharge from the August flow duration curve(s) (USFWS, 2003, pg. 193). Although the habitat accounting system will be based on the August flow, data was also gathered and analyzed for a range of flows to provide an assessment of depth diversity. Within the remainder of this analysis, defined shallow water habitat acreage refers to the following conditions:

- 50% exceedance August flow
- Flow depth less than 5 feet (1.5 m)
- Flow velocity less than 2 ft/sec (0.6 m/s)

The SWH restoration goal is to create 20-30 acres of shallow water per mile. The near term goals of the project are to reach 10% (2,000 acres) of the SWH acreage by 2005 and 30% (5,870 acres) by 2010. Refer to the BiOp for additional information on the SWH performance standards (USFWS 2003, pg 193). BiOp SWH goals computed for each segment using the 30 acre/mile goal and deficit accounting are summarized in Table 1. Comparison is also made to the BiOp segment targets (USFWS 2003, pg 190).

Table 1. BiOp Shallow Water Habitat Goals

BiOp Shallow Water Habitat Goals								
BiOp Segment	RM Range (miles)	BiOp CWCP SWH Base Acres (ac/mi) Current --- Deficit		Year				
				2004	2005	2010	2015	2020
Sioux City - Segment 11 Ponca to Sioux City	753 - 735	2	28	40	50	151	302	504
Omaha - Segment 12 Sioux City to Platte River	735 - 595.5	1.8	28.2	315	393	1180	2360	3934
Nebraska City/St. Joe -Segment 13 Platte River to Kansas City, MO	595.5 - 367.5	4.6	25.4	463	579	1737	3475	5791
Kansas/Boonville -Segment 14 Kansas City, MO to Osage River	367.5 - 130.4	4.6	25.4	482	602	1807	3613	6022
Osage to Mouth - Segment 15	130.4 - 0.0	5	25	265	331	994	1987	3312
Total By Segment				1,565	1,956	5,869	11,738	19,564
Compare to the BiOp Target (Table 9, pg 190)				1,700	2,000	5,870	11,739	19,565

2 Acreage Estimating

Several methods were evaluated for estimating shallow water habitat acres within Omaha District. These methods include:

A. HAMP Data Extrapolated

This method involves extrapolation from twenty bends that have been surveyed one or more times between 2006 and 2009. Collected data is primarily hydrographic survey data.

B. Construction Activity Tabulation

This method involves tabulating all the acreage estimated to have occurred from construction activities both on the main channel and within off channel habitat connected to the main river.

C. GIS Evaluation

Evaluation was performed to determine SWH acreage of the current river within Omaha District using the best available topographic and aerial photos and GIS software.

D. Bathymetric Survey Data

The bathymetric surveys collected within the Omaha District were examined for applicability of computing SWH.

E. Site Field Review

A field review of SWH sites was performed in fall 2009. Notes from the field review were compared to acreage estimates to qualitatively evaluate the different methods.

2.1 SWH Elevation.

SWH acreage estimates are developed with reference to the 50% exceedance discharge from the August flow duration curve. An analysis was conducted to determine the Missouri River shallow water habitat profile from Gavins Point Dam (RM 811) to Rulo, NE (RM 498) and is available within the report *Missouri River, Gavins Point Dam to Rulo, NE, Shallow Water Habitat Profile, August Flow Duration* (USACE, 2007). The performed analysis determined the August flow duration and the corresponding Missouri River elevation throughout the reach. The results provide the basis to evaluate both the depth and velocity SWH criteria at any location along the channelized river in Omaha District.

2.2 SWH Elevation Related to CRP.

The basic reference elevation used for construction and maintenance of the Bank Stabilization and Navigation Project features including dikes and revetments is the Construction Reference Plane (CRP). CRP is a water surface plane that corresponds to the 75% exceedance flow for the navigation season from 1 April through 30 November. CRP is updated frequently with the most recent revision occurring in 2006. Condition of river structures (revetments, dikes) and the extent of repairing those structures is directed according to river flow depth above or below CRP. The SWH acreage flow elevations, which are determined using the August 50% exceedance flow, are a variable difference from the CRP elevations. In order to maintain construction consistency, project design elevations stated on the plans and specifications are related to CRP. The SWH elevation is used in the design process and to estimate created acres.

3 Omaha District - HAMP Data Extrapolated to River

3.1 HAMP Surveys

The Omaha District HAMP Program has collected survey data at portions of twenty bends between 2006 and 2009. No data was collected in 2010. Survey data was collected by the USGS Nebraska and Iowa offices, the Coastal and Hydraulics Lab within the Engineer Research and Development Center, and Omaha District. The data collected at each bend included hydrographic, ADCP, and sediment samples. Variable portions of the complete data set for all twenty bends were collected based on available survey resources and funds. Parameters for the twenty bends included within the Omaha District HAMP survey program are summarized in Table 2.

Table 2. HAMP Program, Omaha District Bend Survey Location

Bend Name	Bend Type - Radius	Upstream River Mile (1960)	Downstream River Mile (1960)	Bend Length (miles)
Glovers Point, Upper	Control-75%	714.3	712	2.3
Decatur, Lower	Control-25%	687.4	686	1.4
Louisville, Upper	Control-25%	686	683.4	2.6
Little Sioux Rch, Upper	Control-75%	676.3	674.8	1.5
Little Sioux Rch, Lower	Dike Notch - 25%	672.8	670.5	2.3
Peterson Cut-off, Lower	Control-75%	659.2	657.8	1.4
Tysons	Dike Notch - 75%	655	651.6	3.4
DeSoto Cut-off	Major Mod.- 75%	644.8	641.8	3
Calhoun, Lower	Control-25%	638.5	637.3	1.2
Boyer, Lower	Major Mod.- 25%	636	634.1	1.9
Tobacco	Major Mod.- 75%	589.4	586.3	3.1
Pin Hook	Dike Notch - 25%	579.2	576.8	2.4
Van Horns	Control-75%	576.8	574.8	2
Civil, Upper	Control-75%	574.8	572.8	2
Civil, Lower A	Control-25%	572.8	571.5	1.3
Copeland, Lower	Control-75%	565.1	562.9	2.2
Nebraska	Dike Notch - 75%	562.9	560.4	2.5
Otoe	Control-25%	556.7	555.5	1.2
Hamburg, Upper	Major Mod.- 25%	555.5	552.9	2.6
Barney, Upper	Control-25%	550.9	549.5	1.4
			Total	41.7

3.2 Velocity Criteria Evaluation

The BiOp SWH definition also has a requirement for velocity less than 2 ft/sec. Distributed velocity within the Missouri River may be evaluated with either a multi-dimensional computation model or with physical field data collected with an Acoustic Doppler Current Profiler (ADCP). Both methods were examined for use with SWH evaluation. Field collected ADCP data was processed to yield the depth averaged velocity and direction throughout each HAMP bend. A limited number of two-dimensional models were also assembled to develop

bend velocity distribution. A comparison of the field measured and model computed bend velocity is shown in Figure 1.

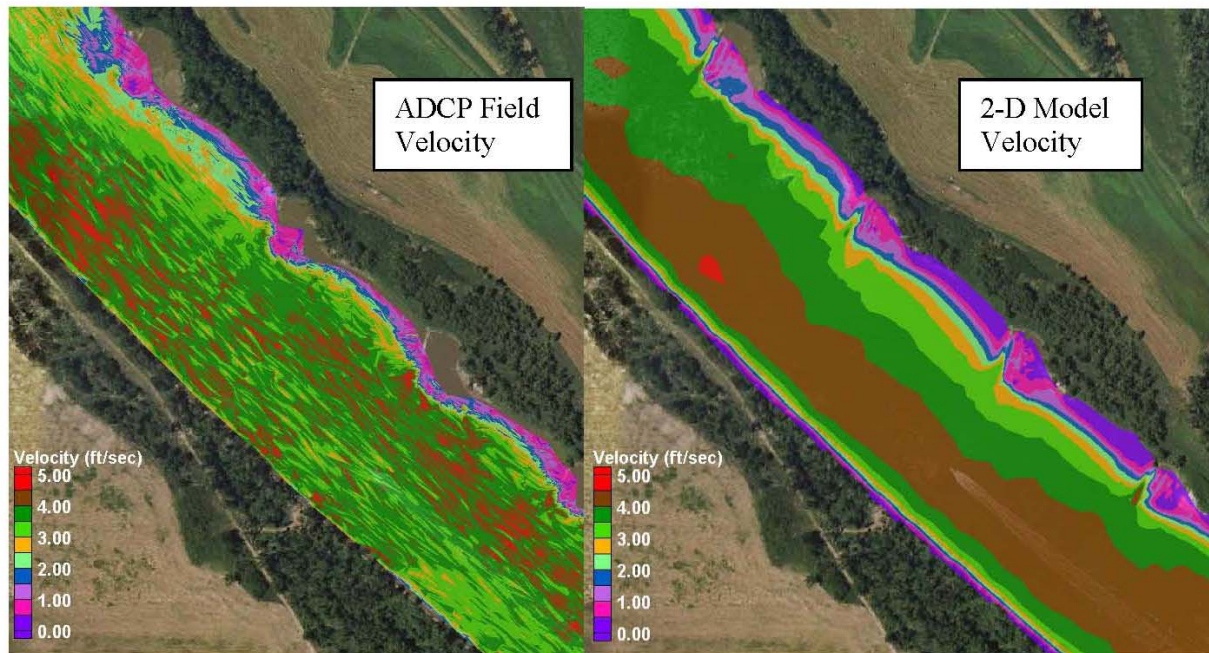


Figure 1. ADCP and Computed Bend Velocity Distribution.

Due to the observed variation in the measured data, caution is recommended when evaluating ADCP data:

- ADCP depth averaged data represents a single snapshot at that specific time. Data collection at a bend requires a long time period during which the Missouri River flow varies.
- ADCP data processing illustrates that numerous spikes occur within the data. This is due to normal river fluctuations characteristic of a large river like the Missouri.
- The depth averaged velocity values are not representative of the 50% August duration flow velocity. ADCP data was usually collected at a different flow rate.
- ADCP data also shows a wide variation within the collected data. For these reasons, ADCP data was not used to evaluate SWH velocity criteria.

Analysis was performed to evaluate inclusion of the velocity criteria. Evaluation of several bends using the 2D model output determined a reduction of an additional 10-15% in the SWH area that meets the depth criteria when the velocity criteria is also included. Additional effort to evaluate the velocity criteria for the entire river was not performed due to the time intensive analysis. After determining areas that meet the depth criteria, a further reduction in acreage of 10-15 % is recommended to reflect the velocity criteria.

3.3 HAMP Bends Acreage Analysis

Analysis was performed to evaluate shallow water habitat acreage and prepare depth shaded maps for the 50% exceedance August flow duration. Analysis was also performed for additional flows to develop shallow water habitat duration curves at each bend. Analysis was performed

using the 2006 through 2008 survey data. A limited data set of 10 bends was collected in 2009 but this data has not been analyzed.

SWH acreage (i.e., approximating flow depths less than 5 feet) was determined using HAMP data from all three survey periods (2006, 2007, and 2008). The data was evaluated for change from 2006 to 2008 using flow durations from the 30%, 50%, and 70% August exceedance.

The HAMP data analysis results indicate a slight decline in SWH from 2006 to 2008. The small magnitude decline may not be significant. However, the data does demonstrate that fluctuation will occur in SWH. The annual variation may be a result of computation methods, data collection methods, the abnormally low flows experienced during the survey period, an actual trend, or a combination of all the above. The analysis of HAMP bend data is complex and can be viewed in a number of different ways. Refer to the annual HAMP evaluation reports (USACE, 2009) for further details. Results of SWH comparisons using HAMP data are summarized in Figure 2.

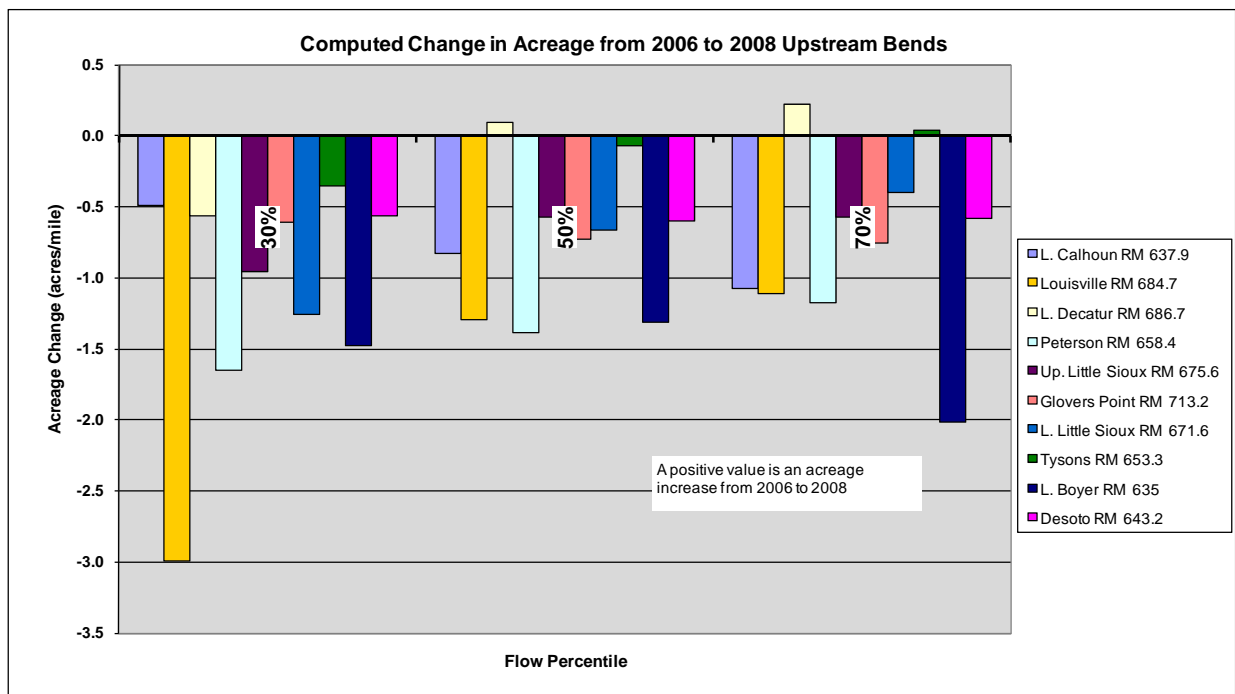


Figure 2. HAMP Data SWH Comparison for 2006-2008.

HAMP data was also evaluated to determine the August 50% exceedance flow average SWH for each bend. Results from this analysis are illustrated in Figure 3.

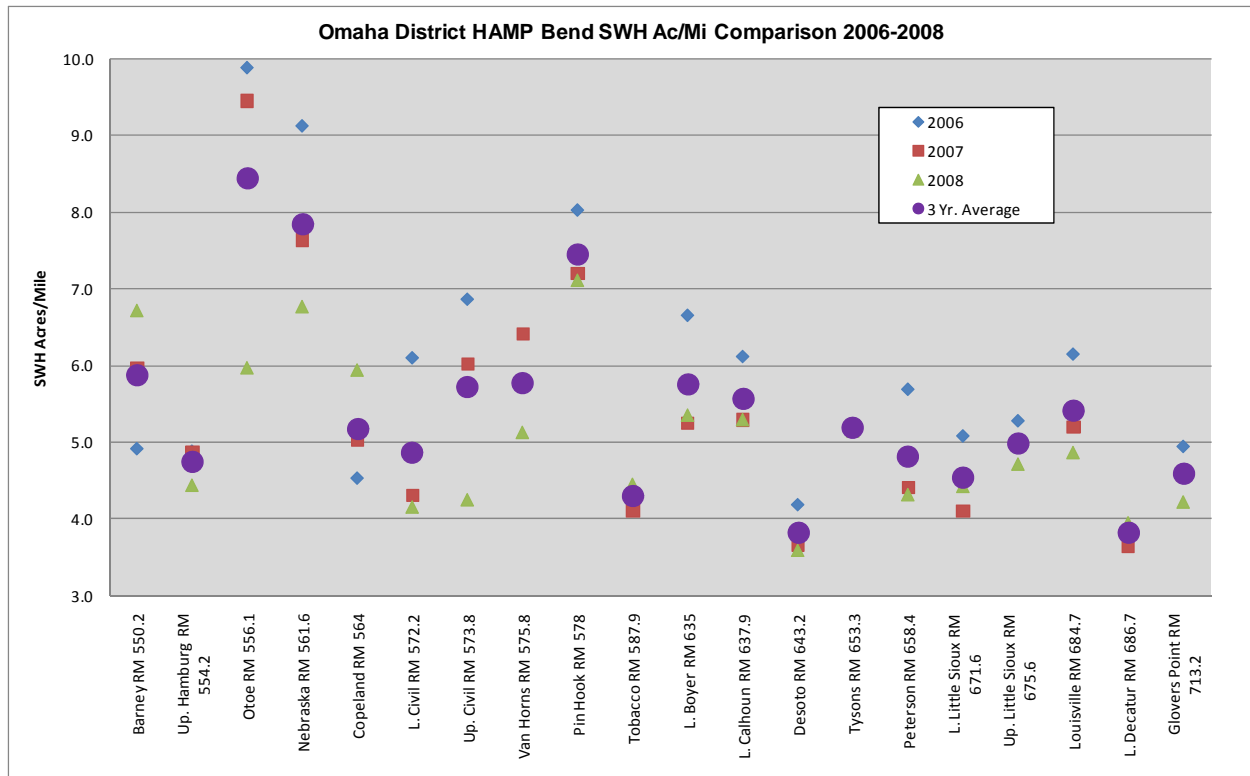


Figure 3. HAMP Data SWH Comparison and Bend Average, 2006-2008.

Due to the significant flow and sediment contribution of the Platte River, and in correspondence to the BiOp defined segments, computations were performed using the HAMP data to define the reach average SWH acres from all bend data for upstream and downstream of the Platte River confluence at River Mile 595. The data is illustrated in Table 3.

Table 3. Omaha District HAMP Bend Annual and Average SWH Acreages

Bend	Bend Length (mi.)	SWH Acreage for Survey Period (ac/mi)				Reach Length Wt. Average (ac/mi)
		2006	2007	2008	3 Yr. Average	
Barney RM 550.2	1.42	4.9	6.0	6.7	5.9	Downstr. Platte River
Up. Hamburg RM 554.2	2.65	4.9	4.9	4.4	4.7	
Otoe RM 556.1	1.18	9.9	9.4	6.0	8.4	
Nebraska RM 561.6	2.6	9.1	7.6	6.8	7.8	
Copeland RM 564	1.3	4.5	5.0	5.9	5.2	
L. Civil RM 572.2	2.19	6.1	4.3	4.2	4.9	
Up. Civil RM 573.8	2.01	6.9	6.0	4.2	5.7	
Van Horns RM 575.8	1.99	5.7	6.4	5.1	5.8	
Pin Hook RM 578	2.39	8.0	7.2	7.1	7.4	
Tobacco RM 587.9	3.08	4.4	4.1	4.4	4.3	
L. Boyer RM 635	1.86	6.7	5.2	5.3	5.8	Upstr. Platte River
L. Calhoun RM 637.9	1.13	6.1	5.3	5.3	5.6	
Desoto RM 643.2	2.96	4.2	3.7	3.6	3.8	
Tysons RM 653.3	3.41	5.2	5.2	5.1	5.2	
Peterson RM 658.4	1.62	5.7	4.4	4.3	4.8	
L. Little Sioux RM 671.6	2.58	5.1	4.1	4.4	4.5	
Up. Little Sioux RM 675.6	1.5	5.3	5.0	4.7	5.0	
Louisville RM 684.7	2.56	6.2	5.2	4.9	5.4	
L. Decatur RM 686.7	1.38	3.9	3.6	3.9	3.8	
Glovers Point RM 713.2	2.32	5.0	4.6	4.2	4.6	

NOTE: Acreage values represent in channel habitat only and do not include any off channel habitat such as chutes and backwaters. Acreage values are also based only on depth criteria and do not include any further reduction due to velocity criteria.

4 Omaha District Construction Activities

Constructed SWH projects have been formulated for numerous types of projects with consideration for site constraints and maintaining all other authorized project purposes including navigation and flood control. A summary of the different types of projects is provided in the following sections. Photographs and field notes regarding current conditions for some of the constructed projects included in the following paragraphs are illustrated in Attachment A.

Acreage estimates were developed for each activity prior to construction. Acreage associated with each activity is based on pre and post field surveys, site assessments, and an estimate of future river dynamics. For each activity, a minimum, maximum, and current acreage value was determined. The minimum and maximum estimates developed prior to construction were based on survey efforts and experience for each activity. The minimum acreage is generally based on

the condition immediately following construction while the maximum acreage reflects an estimate of future changes.

Current constructed acreage totals were estimated using numerous data sources from limited extent surveys extrapolated to all constructed projects. Current acreage estimates for chute and backwater areas were derived from GIS measurements using the best available aerial photos at each site, generally between 2006 and 2009. Current main channel modifications acreages were estimated by extrapolating best available data from the HAMP and GIS analysis.

NOTE: All acreage estimates described in the following sections are based on depth criteria only.

4.1 Chutes

The typical chute layout comprises one or more channels with possible multiple connections to the Missouri River in addition to the entrance and exit. The multiple connections are referred to as secondary connections or tie channels. Chutes are desired to provide a dynamic environment with active bank and bar building processes. River energy limits the location of successful chute alignments. A properly formulated chute will function in both normal and high flow events. Chutes typically include one or more grade control structures to limit degradation within the chute and maintain the proper flow split between the chute and main channel. Past experience has indicated that the chute flow should be about 6-8% of the main channel flow at CRP. Chute alignment and the ratio of the chute length to the main channel length is a good indicator of chute dynamics and sustainability. Due to the sediment load within the chute, it is critical to maintain minimum chute flow velocities to prevent chute aggradation and possible disconnection from the river. Chutes may incorporate variable side slopes to promote depth diversity and woody debris.

A summary of constructed chutes within Omaha District and estimated acreage is provided in Table 4.

Table 4. Omaha District Chute Projects Summary

Chute Projects	Year	Length (ft)	State	Min (ac)	Max (ac)
Fawn Island -- RM 673.3-674.1	2010	2,979	IA	9	13
Middle Decatur Bend -- RM 687.4 - 688.2	2009	4,640	NE	14	20
Lower Calhoun Bend -- RM 637.1 - 637.6	2009	2,750	NE	9	14
Tyson Chute - (w/o upper end) RM 653.1 - 655.5	2009	9,234	IA	12	29
Lower Decatur Chute -- RM 684.9 - 687.3	2008	2,400	NE	9	12
Tobacco Bend Chute Revisions -- RM 586.3 - 588.4	2008	12,000	NE	5	5
Rush Bottoms -- RM 499 - 502	2008	8,400	MO	33	60
Council Bend -- RM 616.8 - 617.8	2007	5,630	IA	18	24
Glovers Point -- RM 711.2 - 713.4	2005	11,100	NE	15	50
Plattsmouth -- RM 592.1 - 594.5	2005	12,070	NE	40	60
Lower Hamburg -- RM 550.6 - 553.4	2005	13,200	MO	21	66
Kansas Bend -- RM 544.5 - 546.4	2005	9,150	NE	35	55
Nishnabotna -- RM 542.4 - 543.3	2005	5,780	NE	10	20
California Bend - NE -- RM 648.5 - 650.1	2003	9,230	NE	10	18
Tobacco Island -- RM 586.3 - 588.4	2002	15,450	NE	17	35
Deroin Bend -- RM 516.4 - 520.5	2002	18,140	MO	20	70
California Bend - IA -- RM 649.5 - 650.1	1999	4,000	IA	4	8
Upper Hamburg -- RM 552.2 - 555.9	1996	15,950	NE	60	100
Boyer Chute -- RM 633.7 - 637.8	1994	16,760	IA	40	60
		Acreage Total		381	719
Number of Projects	19				
Total Chute Length	33.9	(miles)			

4.2 Backwater Areas

Backwater areas consist of a single connection to the Missouri River. The connection location and design features are intended to minimize sediment deposition. However, experience has shown that heavier Missouri River sediments form a bar near the backwater entrance point typically within 3 to 5 years. Deposition also occurs within the entire backwater, although at a slower rate, due to sediment settling as a result of natural river turbidity. General backwater deposition occurs at a slower rate with a backwater life in most locations estimated as 20 to 30 years. Backwaters may also be vulnerable to sediment deposition during high flood events. The more recently constructed backwater areas have incorporated variable side slopes to promote depth diversity and woody debris.

A summary of constructed backwater areas and estimated acreage within Omaha District is provided in Table 5.

Table 5. Omaha District Backwater Projects Summary

Backwater Projects	Year	State	Min	Max
Boyer Backwater -- RM 634.2	2010	NE	43	43
Bullard Bend -- RM 663	2009	NE	25	25
Tyson Backwater -- RM 653.2 (additional acres)	2009	IA	28	68
Plattsmouth Backwater Phase 2 - Plattsmouth	2008	NE	25	25
Hole In the Rock -- RM 706	2006	Tribal	7	10
Blackbird-Tieville-Decatur -- RM 698 - 688	2006	IA	7	10
Glovers Bend -- RM 713 - 711	2005	Tribal	20	28
Plattsmouth Lake connection -- Plattsmouth Chute	2005	NE	20	30
Lower Hamburg -- RM 552 - 556	2005	MO	7	7
California Bend (IA) -- RM 649.5	2004	IA	15	15
Soldier Bend -- RM 660.4	2004	IA	25	25
Tyson Bend -- RM 653.1	2004	IA	25	25
Ponca State Park -- RM 753	2004	NE	60	80
Langdon Bend -- RM 529 - 532	2000	NE	10	20
Louisville Bend -- RM 682 - 685	1995	IA	50	70
	Acreage Total		367	481
Number of Projects	15			

4.3 Main Channel Modifications

Main channel modifications are preformed through channel structure modification. These activities refer to altering the dike and revetment structures that were constructed as part of the Bank Stabilization and Navigation Project (BSNP). Structure modification is proposed to allow channel widening which is desirable to create SWH within the main channel of the Missouri River. Observations indicate a correlation between SWH and increasing the river top width. Generally, the river top width varies from about 650 to 700 feet. Projects are formulated with a goal of adding up to several hundred more feet of top width as the bank erodes over time. Channel widening projects require the modification of the existing dikes to allow bank erosion. River structure modifications are intended to create SWH both directly, by causing deposition within the structure vicinity, and indirectly, by redirecting currents near the bank resulting in increased bank erosion rates and an eventual top width increase. The predominant structure modifications used to create channel widening consist of reverse sills, rootless dikes, dike notching, dike lowering, and chevrons.

The SWH acreage associated with each activity is described in Table 6.

Table 6. Omaha District SWH Estimated Acreage Per Construction Activity

Omaha District Activity	SWH Acreage	
	Min.	Max.
Major Modification (lower 200' dike and construct mid-dike chevron)	8 - 15 ac/mile	
Type B Notch	1	2
New Chevron	0.3	0.6
Revetment Segmenting (50-100')	0.2	0.8
New Rootless Dike / Reverse Sill 75-100'	0.7	1
Modify Chevron / Dike (25' extension / nose / wing)	0.1	0.4
Modify Notch 75' w/New 75-100' Reverse Sill	0.8	1.5
New 75' Dike Notch	0.5	1
New / Modify Dike, Add 75' Notch with 25 - 75' Extension	0.7	1.4
Modify Existing Notch to Add 75'	0.5	1
Bank Tree Actions (ea.)	0	0.1
Chute / Backwater	Varies with Project	

NOTE: Acreage varies at each activity site, the above table represents average values for the minimum and maximum estimated acreage.

Minimum and maximum acreage estimates were developed for each type of channel structure modification prior to construction using the activities values stated in Table 6. The minimum acreage is generally based on the condition immediately following construction while the maximum acreage reflects an estimate of future chute changes. Refer to Attachment B for a listing of structure modifications by individual bend. A summary of structure modifications constructed within Omaha District is provided in Table 7. It should be noted that the estimate for current main channel acreage is less than the minimum acreage previously estimated. Minimum and maximum values were estimated prior to construction based on experience with similar projects. It appears that main channel acreage development is proceeding at a slower pace than projected. In addition, it also appears critical that acreage accounting for main channel modifications should consider overall bend performance as well as individual structure acreage values.

Table 7. Omaha District Channel Structure Modification Projects Summary

Omaha District River Structure Modifications 2004-2010	Number Structure Actions	SWH Acreage	
		Min	Max
Major Modific. (lower 200' dike with mid-dike chevron)	207	145.8	275.8
Type B Notch	123	123	246
New Chevron	11	3.3	6.6
Revetment Segmenting (50-100')	18	3.6	14.4
New Rootless Dike / Reverse Sill 75-100'	48	33.6	48
Modify Chevron / Dike 75' (extension / nose / wing)	34	3.4	13.6
Modify Notch 75' w/New 75-100' Reverse Sill	19	15.2	28.5
New 75' Dike Notch	18	9	18
New / Modify Dike Notch with 25 - 75' Extension	47	32.9	65.8
Modify Existing Notch 75'	69	34.5	69
Bank Tree Actions (ea.)	32	0	3.2
Total Structure Actions	626		
NOTE: SWH acreage totals represent the minimum and maximum acreage estimated with future river dynamics and channel widening.			
SWH Acreage Total		404	789

4.4 Revetment Modifications

Revetment modifications refer to the action of lowering the revetment along the outside of river bend to create a SWH shelf. Shelf width typically varies from 50 to over 150 feet. The shelf may be sloping with a bottom elevation that is typically constructed 3 to 5 feet below CRP. The shelf may also incorporate variable side slopes and woody debris. A summary of constructed revetment modifications and acreage estimates within Omaha District is provided in Table 8.

Table 8. Omaha District Revetment Lowering Project Summary

Revetment Lowering Projects	Year	Length	State	Min	Max
Three Rivers Revetment Lowering RM 670-669.4	2010	2,810	NE	12	18
Lower Decatur Revet. Lower -- RM 685.7 - 687.3	2008	8,200	NE	5	33
Acreage Total				17	51
Number of Projects	2				
Total Revetment Lowered Length	2.1	(miles)			

4.5 Inclusion of Woody Debris

Recent additional guidance to the definition of optimum SWH has stressed the significance of including woody debris. Woody debris structures are a feature suitable for use with all of the stated project types. Structures deployed to date include woody debris within rock structures. The rock is required to maintain placement of the woody debris within the river and prevent flotation. In addition, tree toppling efforts within two selected bends, Kansas and Nishnabotna, as part of the river structure modification contract were awarded in 2009. The intent is to provide woody habitat and also to evaluate bank erosion rates after tree roots are altered.

At this point, additional habitat creation acreage values have not been associated with including woody debris in the structure modifications. Future monitoring may indicate that some acreage benefit occurs when comparing structures constructed with and without woody debris.

4.6 Constructed Acreage Summary

Constructed SWH acres in the Omaha District from 2004 to 2010 were summarized for each activity type as shown in Table 9.

Table 9. Omaha District Construction Summary

Omaha District Missouri River Construction Summary 2004 - 2010 Completed Fall 2009 - River Mile 752 to 498, Omaha District				
Chutes				
	19 Chutes Constructed, 33.9 miles total length			
	* SWH acreage estimated range:	348	to 659	
Backwaters				
	15 Backwater Areas			
	* SWH acreage estimated range:	367	to 481	
Revetment Lowering				
	2 Revetment Lowering Areas, 2.1 miles total length			
	* SWH acreage estimated range:	17	to 51	
Structure Modifications				
	626 Structure Modifications			
	* SWH acreage estimated range:	404	to 789	
All Construction Activities Total		1,136	to 1980	
* Acreage values based on original construction and projected future acreage with geometry growth and Missouri River dynamics.				

4.7 Constructed Acreage Summary by Segment

The BiOp (USFWS 2003, pg 193) contains requirements for SWH by segment. The construction acreage summary may also be viewed in that format as shown in Table 10.

Table 10. Omaha District Construction Summary by Segment
Omaha District - SWH Constructed by Segment

	Segment 11		Segment 12		Segment 13			
	Ponca to Sioux city		Sioux City to Platte Riv.		Platte River to KC			
	RM 753-735		RM 735 - 595		RM 595 - 498 (prorated for Omaha)		Totals	
	Min (ac)	Max (ac)	Min (ac)	Max (ac)	Min (ac)	Max (ac)	Min (ac)	Max (ac)
Chutes			140	248	208	411	348	659
Backwaters	60	80	245	319	62	82	367	481
Revetment Lowering			17	51			17	51
Structure Modifications			162	316	243	473	404	789
Total	60	80	564	934	513	966	1136	1980
Total Acres/Mile	3.3	4.4	4.0	6.7	5.3	9.9	4.5	7.8
Off Channel Acres Total	60	80	402	618	270	493	732	1191
Off Channel % of Total	100%	100%	71%	66%	53%	51%	64%	60%

5 Omaha District GIS Evaluation

Evaluation was performed to determine SWH acreage of the current river within Omaha District using the best available topographic and aerial photos.

5.1 Available Data

Omaha District collected LiDAR data for the portion of the Missouri River from Decatur to Omaha in November 2006. The remainder of Omaha District reach from Sioux City to Rulo was collected in March 2008. The data was collected at low water during the non-navigation season. Collected data included both topographic and aerial photos.

5.2 Aerial Photo Evaluation

The aerial photos collected with the LiDAR data were evaluated to determine correlation with the HAMP data set. A reasonable correlation was observed at each of the HAMP bends between the aerial photo low water top width and the top width computed from the HAMP data analysis for the submerged area greater than 5 foot depth and the area greater than 7 foot depth. Correlation was greater than 0.85 for most bends. The high correlation indicates that the LiDAR data was collected at very low water conditions where all SWH was exposed. Unfortunately, aerial photo coverage with the river level near SWH depth 0, or if the river elevation was equivalent to the river flowing at the August 50% flow level, was not available. Using both photos would have allowed estimating SWH acreage as the difference between the wetted area shown in the two aerial photos. Therefore, evaluation with the aerial photos to determine main channel SWH acreage was not possible.

Additional evaluation was performed using the most recent aerial photos to track the evolution of constructed off channel habitat including chute and backwater areas. The results of this evaluation are tabulated Table 11.

5.3 LiDAR Topographic SWH Evaluation

Since the LiDAR included topographic data points for the SWH data range, this information was used with CADD computation methods to estimate SWH (USACE, 2004). Computation methods using this procedure have been evaluated and were found to produce very accurate results (CRREL, 2008).

Survey data was evaluated with CADD software using the LiDAR data set from March 2008. Unfortunately, the LiDAR data set from November 2006 would have required a significant conversion effort to be suitable for use which was beyond the intent of this evaluation. The LiDAR dataset was evaluated for coverage extent. This data provides accurate information regarding the structure elevation, bank toe, and top of bank elevation. Analysis was performed in accordance with standard operating procedure (SOP) ENG-2001 (USACE, 2006). A river sloping water surface was constructed for the August 50% flow. CADD was employed to compute the difference surface between the sloping water surface and the LiDAR topographic elevations. The difference surface may be shaded to illustrate depth ranges and determine SWH acreage. An example plot of the depth shaded map at Nebraska Bend is shown in Figure 4. Within Figure 4, the red shaded areas correspond to SWH for the August 50% exceedance flow.

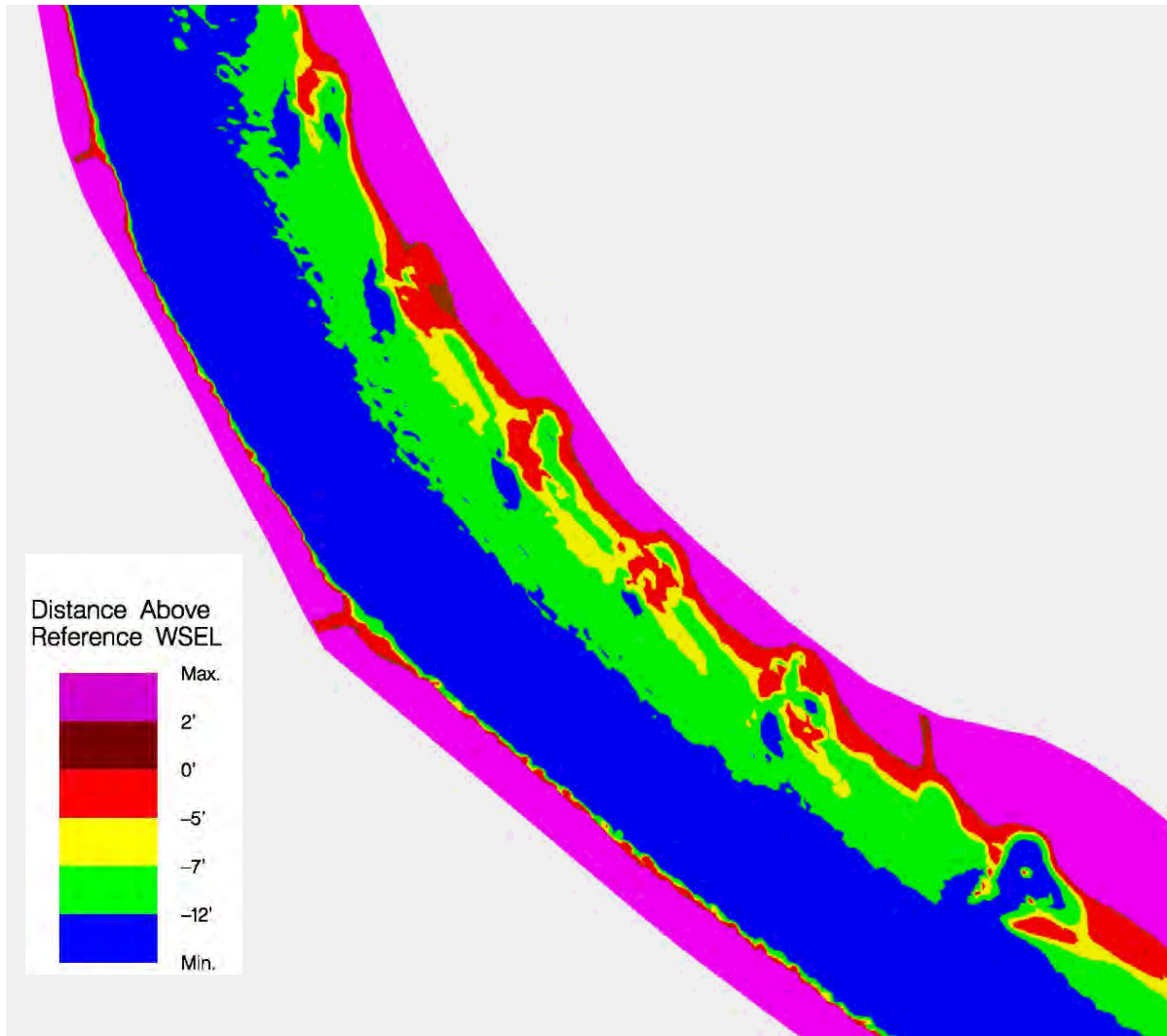


Figure 4. Example Bend Depth Shaded Plot, Nebraska Bend, August 50% Duration Flow

As Figure 4 illustrates, the dominant location of the SWH habitat area is within the dike field on the inside of the bend. The SWH acreage along the outside of the bend which is adjacent to the revetment is relatively minor in comparison. The computed results are summarized in Table 11.

Table 11. Current Omaha District Acreage Estimates using Aerial Photo and GIS Data

US River Mile	DS River Mile	Total Length	Aerial	GIS	Submerged %	GIS Measured Data			Reach Weighted Average ²	
			Photo Low Water Area Acres			Submerged Acres	Difference ¹	SWH Acres	SWH Ac/mi	River Top Width (ft)
753	735.8		No Data Available							
735.8	719.3	16.5	1149	1289	-11%	95	5.8	692	5.6	678
719.3	704.9	14.4	1076	1108	-3%	87	6.0	685		
704.9	690.8	14.1	1036	1073	-4%	79	5.6	674		
691	675	16	No Data Available							
675	649	26								
649	626	23								
626	616	10								
615.7	598.6	17.1	1262	1285	-2%	87	5.1	662		
598.6	595	3.6	No Data Available			30	8.4	625		
Platte River										
595	585.9	9.1	No Data Available			134	14.7	699	11.9	745
585.9	573.4	12.5	1020	901	13%	164	13.1	702		
573.4	558.3	15.1	1271	1122	13%	206	13.6	725		
558.3	543.5	14.8	1300	1241	5%	178	12.0	791		
543.5	531.6	11.9	1043	965	8%	131	11.0	759		
531.6	511.8	19.8	1757	1617	9%	226	11.4	768		
511.8	498	13.8	No Data Available			119	8.6	737		
1 - Submerged difference computed by comaring the low water aerial photo measured acres and the GIS computed submerged acres determined at 5 feet below the SWH August 50% flow exceedance level.										
2 - Reach weighted average determined from the GIS SWH values for above and below the Platte River										
All tabulate values for depth criteria only, do not include velocity criteria.										

NOTE: Acreage values represent in channel habitat based on depth criteria only. Values do not include any off channel habitat such as chutes and backwaters.

6 Omaha District Bathymetric Survey Evaluation

The bathymetric surveys collected within the Omaha District were examined for applicability of computing SWH. The examination concluded a meaningful computation of SWH area could not be determined. Minimum depth for data collection is in the range of 3 feet with typical hydrographic survey equipment. Since the flows within the Omaha District during the time of the survey were abnormally low, available flow depths prevented accurate data collection within the SWH zone. Therefore, this analysis method was not performed within Omaha District.

7 Omaha District Site Field Review

A field review of SWH sites within Omaha District was performed in fall 2009. The purpose of the field review was to evaluate and monitor Missouri River chutes to record how they are performing in an engineering context including items such as erosion, deposition, and flow dynamics. The reconnaissance took place in August – September 2009. Fourteen off-channel chutes were surveyed. The survey included discharge measurements, and a visual inspection of the physical aspects of the chute. The visual inspection focused on physical condition and areas of interest including shoaling in the chute, active erosion, failing/flanking of existing structures, stability, and the presence of other structures such as large woody debris. Refer to Attachment A, the Office Report, *Shallow Water Habitat Reconnaissance, Missouri River Chutes, Omaha District, Aug 2009*, for additional details.

The reconnaissance of the chutes took a substantial effort in 2009. This was the first system wide chute reconnaissance performed by Omaha District. Most of the chutes were observed to be stable and performing as designed. However, future efforts to monitor and document chute performance, erosion, and deposition is required. Chutes that have been identified with obvious problems should be monitored on an annual or more frequent basis. Based on 2009 observations, chutes that require frequent monitoring include both Upper and Lower Hamburg Bend, Kansas Bend, Rush Bottom Bend, and Derooin Bend.

Field observations of significant note are as follows:

- Sandbars are forming or have formed at the inlets of Tobacco Island, Plattsmouth chute, and Glovers Point.
- Chutes at Kansas Bend, Hamburg Bend, and Derooin Bend are all exceeding the design flow rate. Main channel response including shoaling is expected. Chute flow depth and velocity is also exceeding optimum levels for shallow water habitat.
- Construction efforts at Upper Hamburg Bend on the inlet grade control do not seem to be performing as designed. Further monitoring and construction may be required.
- Possible structure flanking from erosion at Derooin Bend and Rush Bottom Bend will require further monitoring. Control structures at most sites appear to be in good condition.
- Chute dynamics is occurring at all sites to some degree. Notably active chutes include Upper Hamburg and Plattsmouth Chute.
- Wood debris was observed within numerous chutes.
- Several chutes appear to be more static. Future reconnaissance efforts should include a task to identify possible locations to add structures within the chute to encourage channel dynamics.

8 Omaha District Comparison of Acreage Estimates

An evaluation was performed of the different acreage estimate methods including survey field data, the aerial photos, LiDAR topography, and the estimated minimum and maximum acres. Separate evaluations were performed for the main channel acreage estimates and off channel chute acreage estimates.

8.1 Main Channel

For the main channel, three different sources of acreage were considered including the HAMP surveys from 2006 to 2008, the LiDAR evaluation that was based on data collected in fall 2008, and the COE estimated construction acres that resulted from channel structure modifications. Comparisons were performed at three bends.

Acreage comparison between the methods is problematic in that a relevant comparison must be performed at the bend level for several reasons including:

- Construction activity may add acres in the structure vicinity but reduce acres at nearby locations within the bend.
- The LiDAR data set and the HAMP surveys are not easily reduced to anything other than a bend level.

- In order to convert the COE estimated structure acres to a bend level, the base or acreage existing within the bend prior to construction activities must be estimated. For evaluation purposes within this report, this acreage was estimated using the segment value within the BiOp (USFWS 2003, pg 193).

The evaluation results are illustrated in Table 12.

Table 12. Omaha District Comparison of Acreage Estimates
Channel Shallow Water Acreage Estimates
Comparison Between Various Methods at Selected Locations

Channel Shallow Water Acreage Estimates Comparison Between Various Methods at Selected Locations						
Bend	Bend Length (mi.)	Hamp Surv. (2006-2008)	LiDAR Evaluation (2008 data)			
		3 Yr. Average (ac/mi)	LiDAR (Acres)	LiDAR (Ac/mi)		
Glovers Point RM 713.2	2.32	4.6	12.1	5.22		
COE Constructed Acres Estimate						
Structure Mod	Year Construct			Bend Ac/Mile		
	Award	Min (acres)	Max (acres)	Base	Min Ac/Mile	Max Ac/Mile
5 Dike Notching with Reverse Sill	2007	4	7.5	2	3.7	5.2
Up. Hamburg RM 554.2		HAMP	LiDAR Eval			
	2.65	4.7	22.63	8.54		
COE Constructed Acres Estimate						
12 Dikes Lowered, 6 New Chevrons	2003	15	26			
3 Dike Extensions, 3 Chevron Modifications	2007	1.2	3			
	Total Thru 2008	16.2	29	4.6	10.7	15.5
6 Chevron Mods	2008	1.2	3			
6 Reverse Sills	2008	4.2	6			
	Total All Activities	37.8	67	4.6	18.9	29.9
Pin Hook RM 578		HAMP	LiDAR Eval			
	2.39	7.4	38.2	15.98		
COE Constructed Acres Estimate						
13 Type B Dike Notch	2004	13	26	4.6	10.0	15.5
6 new notches (5 w/ext.), 7 modify existing notch	2008	10	20			
	Total	23	46	4.6	14.2	23.8

A summary comparison between the three methods is illustrated in Table 13.

Table 13. Omaha District Channel Acreage Summary Comparison
Channel Acreage Summary Comparison

Bend	Acres/Mile			
	Hamp Survey	LiDAR Eval	COE Estimated Constr.	
			Min	Max
Glovers Point RM 713.2	4.6	5.22	3.7	5.2
Up. Hamburg RM 554.2	4.7	8.54	10.7	15.5
Pin Hook RM 578	7.4	15.98	10.0	15.5

Comparison indicates that the HAMP surveys are the lowest value of the three methods at all locations. The LiDAR and COE estimated acreage values are in a similar range. Differences between the methods may be attributed to several reasons including:

- Data are from different seasonal time periods and flow regimes. HAMP data was collected during high summer flows and LiDAR data was collected during low winter flow conditions.
- HAMP data did not include shallow water depths since hydrographic data collection is not feasible at depths less than three feet, accuracy is reduced in the near bank region.
- The LiDAR data set does not reflect depths within isolated pools in the near bank region.

When comparing the LiDAR and HAMP acreage values, it is apparent that each method has potential accuracy concerns. The HAMP data set, which was unable to survey in the near bank region, appears to underestimate actual acreage. The LiDAR dataset, which does not include data within the pools, appears to overestimate acreage in the near bank region due to bed topography variation. A plan view comparison illustrating the difference between the two methods is illustrated in Figure 5.



Figure 5. Comparison LiDAR and HAMP SWH Acreage, Pin Hook Bend.

8.2 Off Channel Chutes

Comparison of COE pre-construction acreage estimates to aerial photo values within off channel chutes was also performed. Chute acreage was measured by delineating the chute area using available aerial photos from 2006 and 2008. The chute acreage represents all off channel area below the top of bank. The comparison of the acreages from the COE estimates and the aerial images indicates that the COE estimated acres are reasonable. A summary of the comparison is included within Table 14.

Table 14. Omaha District Off Channel Acreage Comparison
Off Channel Acreage Comparison at Selected Locations

Chute Projects	Contract Year Award	Length (ft)	State	COE Est. Acres		2006 Aerial Photo Measured (ac) ¹
				Min (ac)	Max (ac)	
Boyer Chute -- RM 637.8 - 633.7	1994	16,760	IA	40	60	56
Upper Hamburg -- RM 552 - 556	1996	15,950	NE	60	100	97
Lower Hamburg -- RM 554 - 546	2005	13,200	MO	21	66	34
Kansas Bend -- RM 546.4-544.5	2005	9,150	NE	35	55	23
Nishnabotna -- RM 543.3 - 542.4	2005	5,780	NE	10	20	19
Plattsmouth -- RM 594 - 592	2005	12,070	NE	40	60	90
Tobacco Bend Chute (Base+Rev.)	2002-08	12,000	NE	22	40	23
1 - Chute acreage from 2006 low water aerial photos. Does not reflect 2010 conditions.						

9 Summary and Recommendations

This document provides an estimate of shallow water habitat acreage within the Omaha District and describes the methodology used to derive the estimate. Acreage estimates were performed using a variety of methods for the 2010 acreage update. **All tabulated acreage estimates are based on depth criteria only.**

Within Omaha District, SWH acreage estimates were prepared from:

- The Omaha District HAMP Program has collected survey data at portions of twenty bends between 2006 and 2009.
- GIS analysis using LiDAR data from 2006 and 2008
- GIS analysis using low water aerial photos from 2006 and 2008
- Construction acreage estimates

Comparison of the different acreage values illustrates a wide range of values. Significant conclusions regarding differences between the methods are:

- Data are from different seasonal time periods and flow regimes. HAMP data was collected during high summer flows and LiDAR data was collected during low winter flow conditions.
- HAMP data did not include shallow water depths since hydrographic data collection is not feasible at depths less than three feet, accuracy is reduced in the near bank region.
- The LiDAR data set does not reflect depths within isolated pools in the near bank region.

Analysis was also performed to evaluate the accuracy of COE estimated construction activity SWH acres. Based on the different measurement methods, it appears that:

- Construction activity estimated acres from within channel activities like dike notching are likely higher than actual. This is due to a number of factors including measurement methods and the slow pace of channel widening. A time frame to reach the optimum channel width that maximizes SWH productivity while maintaining authorized project purposes has not been estimated. Based on observations to date, it may be decades.
- Estimated acres within off channel habitat appear to be of good quality compared to actual values.

Future SWH acreage accounting efforts should consider the following:

- Acreage estimates should transition from only considering additional acres from construction to a method based on actual acres within the river. At the conclusion of the SWH construction program, actual acres will become the critical value.
- All off channel August flow wetted acreage that is directly connected to the main channel within chutes, backwaters, and side channels is tabulated as SWH without regard to depth or velocity.
- Acreage estimates should recognize that habitat is dynamic. Any measurement is a snapshot in time of changing conditions. Further evaluation should be performed regarding the best time period and methodology for measuring acreage. Measurement methodology should be consistent to allow accurate comparison of SWH acres over time.
- Future SWH acres measurement methodology should include both a total acres component and a quality component. Methodology to assess SWH acres quality has yet to be determined.
- The BiOp SWH acreage value focuses on the Aug. 50% flow duration. Computation of SWH acreage may also be performed for additional flow duration values to determine a habitat duration curve. This provides a depth diversity description that should also be evaluated and may be a quality component.
- The BiOp includes a SWH acres velocity metric of less than 2 ft/sec that would require detailed evaluation. Based on current information, the shift to a depth only acreage target is recommended. Velocity could be incorporated as one of the quality components.
- The tabulation of actual SWH acreage values by segment is revealing in that the original BiOp estimates were probably off target. Actual acreage estimates within each segment may be a significant factor to consider in future recovery actions.

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Attachment A



**US Army Corps
of Engineers®**
Omaha District

OFFICE REPORT
Shallow Water Habitat Reconnaissance
Missouri River Chutes, Omaha District
AUGUST 2009



Photo of Kansas Bend Chute

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Shallow Water Reconnaissance, Missouri River Chutes August 2009

1. INTRODUCTION

As part of the Missouri River Recovery program, the Omaha District, in partnership with various other local and government organizations, has created various off-channel chutes and backwaters to increase the amount of shallow water habitat and habitat diversity for the species that live in the river. This report investigates only Missouri River chutes within the Omaha District, from Sioux City, IA, to Rulo, NE.

The typical chute layout comprises one or more channels with possible multiple connections to the Missouri River in addition to the entrance and exit. The multiple connections are referred to as secondary connections or tie channels. Chutes are desired to provide a dynamic environment with active bank and bar building processes. River energy limits the location of successful chute alignments. A properly formulated chute will function in both normal and high flow events. Chutes typically include one or more grade control structures to limit degradation within the chute and maintain the proper flow split between the chute and main channel. Past experience has indicated that the chute flow should be about 6-8% of the main channel flow at normal navigation season flows. Chute alignment and the ratio of the chute length to the main channel length is a good indicator of chute dynamics and sustainability. Due to the sediment load within the chute, it is critical to maintain minimum chute flow velocities to prevent chute aggradation and possible disconnection from the river. Chutes may incorporate variable side slopes to promote depth diversity and woody debris.

1.1 Study Purpose

The purpose of this reconnaissance study was to evaluate and monitor Missouri River chutes to record how they are performing in an engineering context including items such as erosion, deposition, and flow dynamics. Data collected during the field reconnaissance will be used to make informed decisions regarding future project formulation.

1.2 Study Scope

The reconnaissance took place in August – September 2009. Fourteen off-channel chutes were surveyed. The survey included discharge measurements, and a visual inspection of the physical aspects of the chute. Discharge measurements were taken upstream of the inlet to obtain a total discharge of the river. The discharge measurements were taken with acoustic Doppler current profiler (ADCP) equipment according to the USGS SOP. The measured discharge was compared to the nearest gage station on the river. Flow measurements were also performed in the chute and the Missouri River downstream of the chute inlet. The addition of the chute discharge to the downstream discharge provides a check by using the gage and the upstream discharge measurement to perform a flow balance.

The visual inspection checked for issues such as shoaling in the chute, active erosion, failing/flanking of existing structures, stability, and the presence of other structures such as LWD.

1.3 Past Studies

The reconnaissance for the backwater sites, where no flow is present was conducted earlier in 2008-09. This report is included as Attachment 1 to this report. Although previous discharge measurements have

been conducted in the past at selected chute sites, this is the first all-inclusive reconnaissance done to date where all chutes were evaluated in the same time period.

2. Site Conditions.

Table 1 summarizes measured flow data.

Table 1 - 2009 Missouri River Chute Surveys						
Location	Survey Date	Inlet-Outlet 1960 River Mile	Gage Reading (cfs)¹	ADCP Discharge (cfs)	Chute Discharge (cfs)	Chute Velocity (fps)
Glovers Chute	8/26/2009	713.6-711.2	30000 ^D	31250	495	1 - 2
Middle Decatur Chute	8/31/2009	688.2-687.4	32300 ^D	32229	1305	3 - 6
Lower Decatur Chute	8/31/2009	685.4-684.8	32300 ^D	32733	1448	1.5 - 2.2
California Bend (IA)	8/25/2009	650.1-649.6	31100 ^O	32104	2035	2 - 3
California Bend (NE)	8/25/2009	650.05- 648.5	31100 ^O	29564	2063	2 - 3
Boyer Chute	8/28/2009	637.9-633.5	33400 ^O	33776	2045	1.5 - 2.5
Council Bend	9/2/2009	617.6-616.7	32900 ^O	33341	1978	2.5 - 3.5
Plattsmouth Chute	9/1/2009	594.5-592				1.5-2.5
Tobacco Island	9/1/2009	589.5-586.5	38900 ^N	39712	859	2.5 - 3
Upper Hamburg (NE)	9/4/2009	555.7-552.2	42600 ^N	43944	4972	2 - 3
Lower Hamburg (MO)	9/4/2009	553.2-550.7	42600 ^N	38256	2731	2 - 3
Kansas Bend	8/27/2009	546.4-544.6	41300 ^N	41770	7424	4 - 5
Nishnabotna Bend	8/27/2009	543.6-542.5	41300 ^N	38720	2957	2.5 - 3.5
Derooin Bend	8/27/2009	520.5-516.5	41400 ^R	41662	5235	2.5 - 3.5
Rush Bottom	9/2/2009	502-498.7	39500 ^R	40253	1245	1.5 - 2.5

1 Refers to nearest gage applicable to site, D = Decatur, O=Omaha, N=Nebraska City, R=Rulo

2.1 Glovers Point Chute

Glovers point chute (see Figures 1 and 2) was visited on August 26 when the Sioux City gage was reading 30,000 cfs. This chute represents the lowest flowing of all the chutes that were surveyed. On the right bank of the chute, just inside the inlet there is a sandbar forming. At this flow, the sandbar was approximately 6" under water. At such low flows and velocities, erosion is not expected and was not observed in the chute. However, the bridge across the chute was impassable so a full visual survey of the chute was not completed. The lower end of the chute was also too shallow to permit passage.

The bridge crossing the chute (see figure3), connecting the main-land to the island looks as if it will become clogged with debris and present a maintenance problem if left unattended. A good quantity of debris can already be seen that has become hung up on the piers of the bridge.

The riprap lining the inlet of the channel looked to be in fine, stable condition. The sills in the river at this bend were between 3-4' out of the water.



Figure 1 - Photo August 2008 Glovers Point inlet.

Deposition is occurring in the downstream area of the chute and entrance to the backwater area. Deposition bars can be seen in Figure 2 and deposition was verified in the 2008 surveys from near the backwater entrance to the outlet. The design for the backwater area had 2 holes about 12 to 15 deep, one in each arm.



Figure 2 – Photo August 2008 Glovers Point outlet. Note chute and backwater



Figure 3 - Photo August 2009 Glovers Point upstream of bridge looking downstream.

2.2 Middle Decatur Chute

The chute at Middle Decatur Bend was inspected on August 31 when the gage at Decatur read 32,300 cfs. Flows in the chute were less than 5% of the river's flow. Engineered large woody debris (LWD) structures that were placed during construction are still stable and in place in the chute. Active erosion is occurring in the chute (see figure 5 and 6) as witnessed by sloughing and vertical banks. Erosion seems to be caused by the eddying motion of the water passing over the rock inlet, and the eddying motion of the water around the woody debris and the bank material (sugar sand).



Figure 4 – Photo September 2009. Middle Decatur during September high water



Figure 5 – Photo August 2009 Middle Decatur inlet. Bank protection at inlet looks stable.



Figure 6 – Photo August 2009 Middle Decatur Chute, in chute looking upstream . Vertical eroding banks on both sides of chute. Bank material consists of sand.

2.3 Lower Decatur Chute

Lower Decatur Chute was surveyed on August 31 when the gage at Decatur read 32,300 cfs. Flow in the chute is less than 5% of the river. Velocities in the chute were between 1.5 and 2.2 fps. Very little active erosion is occurring in this chute.



Figure 7 – Photo August 2008 Lower Decatur. Photo during construction



Figure 8 – Photo August 2008. Lower Decatur.



Figure 9 – Photo August 2009 Lower Decatur. Note vegetation, but still some bank erosion.

2.4 California Bend Chute (Iowa)

The California Bend chute in Iowa (Figure 10) was surveyed on August 25 when the gage at Omaha was reading 31,100 cfs.

Chute measured velocities were between 2-3 fps. Active erosion was observed on both banks throughout the chute (figure 11 and 12). The downstream $\frac{1}{4}$ of the inlet is clogged with trees and debris, causing low velocities in the chute just downstream of this blockage. This has caused some deposition downstream of the inlet.



Figure 10 - Photo September 2008 California Chutes, looking downstream. Iowa on left (with backwater), Nebraska on right. Note deposition inside chute by woody debris.



Figure 11 – Downstream of outlet looking upstream at chute and backwater. Note steep banks along chute.



Figure 12 – Looking upstream. 4-23-09

2.5 California Bend Chute (Nebraska)

The California Bend chute in Nebraska was surveyed on August 25 when the gage at Omaha was reading 31,100 cfs. The Nebraska side of California Bend has two inlets and three outlets. The inlets (Figure 13) were both too shallow ($<4'$) to accurately measure the discharge with our limited capability. Velocities were about 2 fps. Very little active erosion is occurring in this chute, except near the upstream inlet. A sandbar is beginning to form on the right bank just downstream of where both inlets come together.

A rock structure (dike remnant) is present just downstream of the first outlet. There is an 18 foot deep hole on the downstream side of this structure. There was no water flowing at either of the first two outlets at the time of survey. The second outlet has a slightly wider channel and more standing water than the most upstream (first) outlet. These outlets are connected at higher flows.



Figure 13 – California Chute Inlets, NE. Looking downstream



Figure 14 – Photo August 2008 downstream of California Chute NE (near) looking upstream at outlets.
Note the most upstream of the 3 outlets is hidden by trees.



Figure 15 – Photo April 23, 2009 California Chute NE looking at the most upstream outlet, which only functions at a relatively high flow.

2.6 Boyer Chute

Boyer Chute was surveyed on August 28 when the gage at Omaha was reading 33,400 cfs. Depths ranged between 6 and 9 feet with velocities between 1.5 and 2.5 fps. A scour hole that is 45 feet deep has formed just inside the inlet (Figure 17). Just downstream of the bridge (Figure 18) connecting the island to the mainland, another hole, 30' deep has also formed. The Fish and Wildlife service reports that the left bank, just downstream of the bridge has been eroding approximately 10 feet per year.

There is an abundance of dead, fallen and standing timber (Figure 18) in the chute and on the overbanks that is generally not observed in many of the other chutes. Figure 19 shows the lower section of the chute including the outlet.



Figure 16 – Photo September 2008. Inlet of Boyer Chute in foreground with the outlet and Missouri River in the background, approximately 2.5 miles downstream of inlet.



Figure 17 – Photo August 28, 2009. Looking downstream at bridge in Boyer Chute



Figure 18 – Photo August 28, 2009. Note logs on bank.



Figure 19 – Photo August 28, 2009

2.7 Council Bend Chute

Council Bend was surveyed on September 2 when the gage at Omaha was reading 32,900 cfs. Depths ranged from 5-10 feet with velocities between 2.5 and 3.5 fps. No active erosion was visible in this chute. A number of engineered woody debris structures are still intact. There was a noticeable increase in the number of geese and ducks, which is probably due to the abundance of gently sloping banks in this chute, which isn't seen in many of the other chutes.



Figure 20 - Photo September 2008. Looking upstream



Figure 21 – Photo September 2009. At inlet looking downstream, Omaha skyline in view.

2.8 Plattsmouth Chute

Plattsmouth chute was surveyed on September 1, 2009. Velocities in the chute were between 1.5 and 2.5 ft/sec. Depths were between 2 and 4 feet and the width was on average 160 feet.

Deposition and erosion occurred throughout the chute. Signs of deposition in the chute include a sand bar developed along the right bank of the chute at and downstream of the inlet, Goose Lake and the chute are only connected during relatively high flows due to deposition in both the inlet and outlet, and many bars have developed in the chute itself. Banks on both sides are steep and erode due to the flow being direct to it or by changing water surfaces.



Figure 22 - April 23, 2009. Inlet to Plattsmouth chute with Platte and Missouri River confluence in the background. Note deposition in chute downstream of inlet.



Figure 23 – Photo April 23, 2009. Inlet at Plattsmouth, note erosion of bank which is across from deposition in previous figure.



Figure 24 - September 1, 2009. Note deposition at inlet to Goose Lake.



Figure 25 – Photo April 23, 2009. Plattsmouth Chute outlet

2.9 Tobacco Chute

Tobacco chute was surveyed on September 1, 2009 when the Nebraska City gage flow was 38,900 cfs. Velocities in the chute were recorded between 2.5 and 3.0 feet. Deposition was occurring at the upstream side of the inlet. The width of the chute was fairly uniform throughout its length.



Figure 26 - April 2009. Photo of inlet to Tobacco chute



Figure 27 – April 2009. Looking downstream in middle area of Tobacco Chute



Figure 28 – April 2009. Tobacco chute outlet

2.10 Upper Hamburg Chute

Upper Hamburg chute was surveyed on September 4, 2009 when the gage at Nebraska City was reading 42,600 cfs. At these flows, a hydraulic jump occurs at both the revetment notch and at the inlet grade control. Improvements to the grade control were made in December 2008. Figure 31 shows the chute under repair in 2008. Depths through the grade control notch show a bottom elevation of 900-901. The designed bottom of the notch is 902.2. The cause of this discrepancy has not yet been discovered, but might be due to higher than expected velocities through the notch washing material downstream. Downstream of both the revetment notch and the inlet grade control, there are large 30-40 foot deep scour holes. No plan has yet been developed to fix this problem, and flows through the chute are still exceeding the design standard of 8-10% of total river flow. Structures constructed in the river in combination with high flows have temporarily solved the shoaling problem within Hamburg bend.

The chute looked very natural with both areas of erosion and deposition (Figures 32-34).



Figure 29 - 2008. Upper Hamburg is in the background with lower Hamburg in the foreground.



Figure 30 - April 2009. Downstream of grade control looking upstream



Figure 31 - December 17, 2008. Construction repair to the upstream grade control.



Figure 32 - April 23, 2009. Chutes interior, note overbank vegetation.



Figure 33 - September 15, 2009. Photo of the river bank in Hamburg Chute.



Figure 34 - September 15, 2009. Photo of the river bank in Hamburg Chute.



Figure 35 - April 23, 2009. Outlet

2.11 Lower Hamburg Chute

Lower Hamburg chute was surveyed on September 4, 2009 when the gage at Nebraska City was reading 42,600 cfs. The chute is fairly uniform with steady depths except just below the grade controls where the depth increases a few feet. A connection with a backwater area occurs near the center of the chute on the left bank. The connection occurs only during high flows.



Figure 36 - Photo August 2008. Downstream of outlet, looking upstream at Lower Hamburg chute.



Figure 37 – Photo September 2009. Looking downstream, past the inlet and into the lower Hamburg Chute.

2.12 Kansas Chute

Kansas Chute was surveyed on August 27, 2009 with the gage at Nebraska City reading 41,300 cfs. The depths were upwards of 15 feet with velocities between 4 to 5 fps (highest recorded of all chutes). Flows in Kansas Bend were 18% of the river discharge. The chute is designed for 8-10%. Measures are being taken to remedy this problem. The inlet grade control will be raised to limit the amount of flow through the chute similar to what was constructed at Hamburg in 2008. Erosion was occurring along most of the banks. Six sediment rangelines were established and surveyed in 2009.



Figure 38 – Photo September 2009. Looking downstream at Kansas Chute

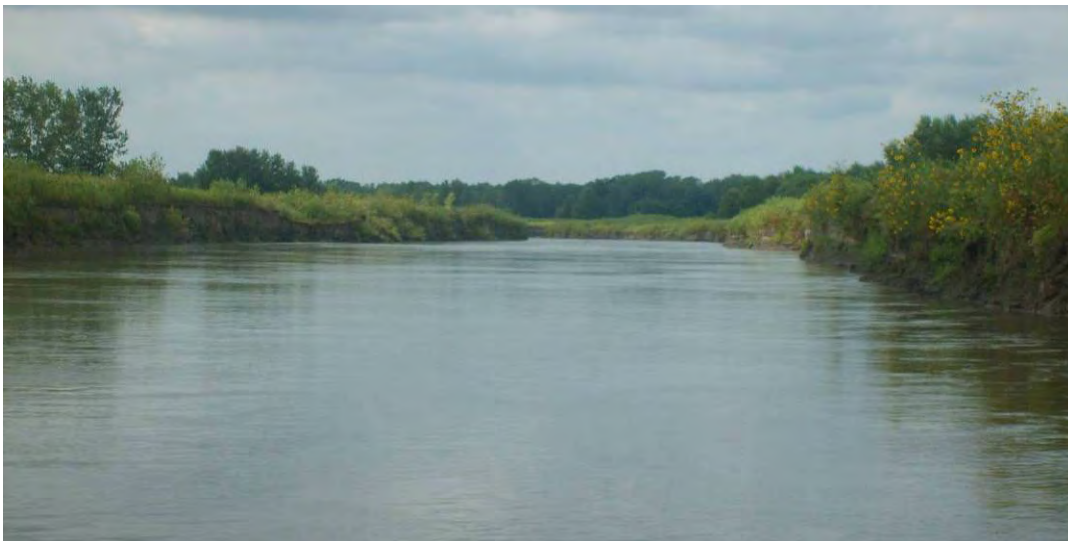


Figure 39– Photo August 2009. Looking downstream in the Kansas Bend Chute.

2.13 Nishnabotna Chute

Nishnabotna chute was surveyed on August 27, 2009 with the gage at Nebraska City reading 41,300 cfs. The chute is relatively short with a slow moving current. Depths averaged about 9-10 feet and the width was 120 feet. There is noticeable erosion on the left bank and some vertical banks showing some recent erosion. The dike that comes in from the left bank of the chute just downstream of the inlet is completely clogged with woody debris.



Figure 40 – Photo September 2009. Flow is from right to left.



Figure 41 – Photo August 2009. Looking upstream in the Nishnabotna Chute.

2.14 Deroin Bend Chute

Deroin Chute was surveyed on August 27, 2009 when the gage at Rulo was reading 41,400 cfs. The chute is about 9 feet deep and 250-300 feet wide. Flows in the chute are 13% of the river flow – slightly higher than the designed flow. No rock was visible on the inlet grade control structure on the right bank of the chute. On the left bank, the bank has eroded and the structure might be in danger of being flanked on this side. The dikes just downstream of the grade control structure are no longer visibly attached to the bank. They appear as large standing piles of rock in the chute.



Figure 42 – Photo September 2009. Looking South at the Deroin Bend Chute



Figure 43 – Photo August 2009. Looking at the Deroir Bend Chute outlet



Figure 44 - Photo August 2009. Looking downstream into the chute (left side)

2.15 Rush Bottom Chute

Rush Bottom Chute was surveyed on September 2, 2009 when the gage at Rulo, NE was at 39,500 cfs. There is active erosion occurring on the left bank just downstream of the inlet. See Figure 45.



Figure 45 – September 2009 inlet to Rush Bottom Chute. Note vertical bank and woody debris.

Vertical banks throughout also indicate active erosion. Both grade control structures are in good condition with rock visible on both banks. The banks have eroded back farther than the edges of the structure. The structures do not appear to be in immediate danger of being flanked but monitoring of this

situation is recommended. See Figure 46.



Figure 46 – Grade control structure showing extents of erosion.

3. Summary

Reconnaissance of the chutes took a substantial effort in 2009. This was the first system wide chute reconnaissance performed by Omaha District. Additional reconnaissance is anticipated to be required through either the Missouri River Recovery Program or the Corps of Engineers Operation and Maintenance Program. Most of the chutes are observed to be stable and performing as designed. Future efforts to monitor and document chute performance, erosion, and deposition is required. Flow comparison measurements can be accomplished with ADCP as the need arises. Chutes that have been identified with obvious problems should be monitored on an annual or more frequent basis. Based on 2009 observations, chutes that require frequent monitoring include both Upper and Lower Hamburg Bend, Kansas Bend, Rush Bottom, and Derooin Bend.

Sediment rangelines have not been established at numerous chutes and are necessary to evaluate erosion and deposition. Establishing a history of repetitive surveys also provides detailed information regarding chute dynamics and trends. Chutes to establish rangelines and perform initial survey include:

- Boyer chute (new const.)
- Fawn Island
- Glovers Point
- Lower Hamburg (Missouri)
- Middle Decatur
- Rush Bottom

A number of chutes also have not been surveyed since the original survey and monummentation. Chutes should be surveyed every few years for monitoring purposes. Some chutes have not been surveyed in over 5 years. Chutes that are recommended to be surveyed along with their last survey date include:

- Boyer Chute – 1998
- California Bend (Iowa) – 2002
- Nishnabotna Bend - 2002
- Derooin Bend – 2003
- California Bend (NE) – 2004

Field observations of significant note are as follows:

- Sandbars are forming or have formed at the inlets of Tobacco Island, Plattsmouth chute, and Glovers Point.
- Chutes at Kansas Bend, Hamburg Bend, and Derooin Bend are all exceeding the design flow rate. Main channel response including shoaling is expected. Chute flow depth and velocity is also exceeding optimum levels for shallow water habitat
- Construction efforts at Upper Hamburg Bend on the inlet grade control do not seem to be performing as designed. Further monitoring and construction may be required.
- Possible structure flanking from erosion at Derooin Bend and Rush Bottom Bend will require further monitoring. Control structures at most sites appear to be in good condition.
- Chute dynamics is occurring at all sites to some degree. Notably active chutes include Upper Hamburg and Plattsmouth.
- Wood debris was observed within numerous chutes.
- Several chutes appear to be more static. Future reconnaissance efforts should include a task to identify possible locations to add structure within the chute to encourage channel dynamics.

Attachment B

Omaha District
Structure Modification Summary - Construction Projects Awarded Through 2009

Project Acquisition Method	Structure Construction Type	Bend Location	River Mile Range	Contract Yr Award	Major Modific. (lower 200' dike, add chevron)	Type B Notch	New Chevron	Revetment Segmenting (50-100')	New Rootless Dike / Reverse Sill 75-100'	Modify Chevron / extension / nose / wing	Modify Notch 75' w/New Rev. Sill	New 75' Dike Notch	New / Modify Dike, Add 75' Notch w/ 25 - 75' Exten.	Modify Existing Notch to Add 75'	Bank Tree Actions (ea.)	Total Structure Actions
DACW45-03-C-0008	Major Mod. (Modify Dike, New Chevron)	Upper Hamburg	553.05 - 554.8	2003	18	(12 Dikes Lowered, 6 New Chevrons)										74
		Lower Hamburg	550.9 - 552.4		17	(11 Dikes Lowered, 6 New Chevrons)										
		Lower Barney	547.1 - 548.8		21	(14 Dikes Lowered, 7 New Chevrons)										
		Upper Kansas	544.8 - 545.85		11	(7 Dikes Lowered, 4 New Chevrons)										
		Nishnabotna	542.3 - 543.1		7	(5 Dikes Lowered, 2 New Chevrons)										
Task Order #3	Major Mod. (Modify Dike, New Chevron)	Snyder	715.45 - 715.92	2004	9	(6 Dikes Lowered, 3 New Chevrons)										127
		Winnebago	708.79 - 709.92		17	(11 Dikes Lowered, 6 New Chevrons)										
		Desoto	642.51 - 643.98		17	(11 Dikes Lowered, 6 New Chevrons)										
		Boyer	634.21 - 636.97		27	(18 Dikes Lowered, 9 New Chevrons)										
		Tobacco	586.57 - 588.86		27	(18 Dikes Lowered, 9 New Chevrons)										
		Langdon	529.32 - 531.57		30	(20 Dikes Lowered, 10 New Chevrons)										
Hired Labor	Type B Dike Notching	Lower Dakota	722.1 - 722.5	2004		5										123
		Lower Monona	699.6 - 700.8			10										
		Upper Blencoe	678.9 - 679.6			6										
		Sandy Point	656.5 - 657.4			7										
		Lower Little Sioux	670.5 - 672.4			14										
		Tyson	653.1 - 655.4			7										
		Rock Bluff	582.8 - 584.8			15										
		Pin Hook	576.8 - 578.7			12										
		Copeland	565.4 - 569.2			21										
		Nebraska	561.5 - 562.7			8										
		U/L Deroin-Indian Cave	516.3 - 519.7			17										
		Cottier	508.4			1										
Task Order 8	New Rootless Dike, Reverse Sill, Chevron Mod	Winnebago	708.8 - 709.8	2006					5	5						25
		Omaha Misson	704.5 - 705.0						3							
		Lower Blencoe	677 - 677.2						2							
		Sandy Point	656.5 - 657.2								4					
		Upper Manawa	606.7 - 608.2											6		
Task Order 12	Revetment Segmenting	St Mary's	596.5 - 597.6	2006	(6 Segments)			6								18
W9128F-04-D-0012		Desoto	642.0 - 643.7	2007	(12 Segments)			12								
Task Order 16	Notch Dike, New Rootless Dike, Reverse Sill, Chevron Mod.	Glovers Point	711.1 - 711.9	2007							5					32
		Upper Plattsmouth	592.2 - 593.5								6			6		
		Tyson	651.8 - 654.3				11			4						
Task Order 17	Mod Existing Dike	Middle Decatur	687.8 - 688.2	2007	6	(6 Dikes Lowered, varying length 120-380 ft)										6
Hired Labor	Reverse Sill, Chevron Mod	Little Sioux	670.6 - 670.9	2007							2					11
		Boyer	635.6						1							
		Tobacco	587.3						1							
		Nebraska	561.8								1					
		Upper Hamburg	553 - 553.9								6					
Task Order 5	New or Modify Notch, with Extension, Rootless Dike, Reverse	Lower Little Sioux	670.5 - 672.36	2008							1	3	6	8		
W9128F-08-R-0024		Desoto	642.25 - 643.25						6							
		Middle Blencoe	678.8 - 679.56								3	3				
		Lower Boyer	634.32 - 636.97						11							41
Task Order 6	New or Modify Notch, with Extension, Rootless Dike, Reverse	Upper Hamburg	552.9 - 555.5	2008					6							
W9128F-08-R-0024		Pin Hook	576.8 - 579.2									6	5	2		
		Nebraska	560.4 - 562.9										6	4		
		Tobacco	586.3 - 589.4						9							
		Rock Bluff	582.7 - 586.3									1	5	10		
		Upper Copeland	565.4 - 569.2										2	2		
Hired Labor	Rootless Dike, Chevron Mod	Desoto	642.1 - 643.1	2008						6						58
		Boyer	634.2 - 636.9							7						
		Upper Hamburg	552.9 - 554.7							7						
		Lower Hamburg	551.2 - 552.1							3						
Task Order 4	New or Modify Notch, with Extension, Rootless Dike, Reverse	Copeland Bend	566.2 - 569	2009									7	12		23
W9128F-08-R-0025		Lower Kansas Bend	544.6 - 545.9									3	3	4	20	
		Nishnabotna	542.2 - 543.3										3	2	12	
		Langdon	529.4 - 531.3										5	11		
		Indian Cave Bend	517.6 - 518									2	2	2		
				Totals	207	123	11	18	48	34	19	18	47	69	32	88

All Work Total Structure Actions 626

Appendix B

Missouri River Shallow Water Habitat Report - 2010 Kansas City District

Shahrzad Jalili
Hydraulic Engineer

The Missouri River Fish and Wildlife Mitigation Program (Mitigation Program) was authorized by the Water Resources Development Acts of 1986 and 1999 (WRDA86 and WRDA99) to develop fish and wildlife habitat along the lower Missouri River from Sioux City, Iowa, to the mouth near St. Louis, Missouri, to mitigate for the loss of habitat that resulted from construction, operation, and maintenance of the Missouri River Bank Stabilization and Navigation Project (BSNP). In November of 2000, and as amended in 2003, the US Fish and Wildlife Service issued a Biological Opinion (Bi-Op) to the Corps for impacts to pallid sturgeon by construction and operation and maintenance of the Bank Stabilization and Navigation Project (BSNP). The Bi-Op requires the Corps to enhance and conserve shallow water habitat (SWH) in the amount of 20-30 acres per mile, or approximately 20,000 acres over the project's 735 river miles. The near term goals are to create 10% (2000 acres) of SWH by 2005 and 30% (5870 acres) by 2010. The effective discharge is defined as the 50% exceedance discharge from the August flow duration curve (USFWS,2003). Defined shallow water habitat acreage refers to the following conditions:

- 50% exceedance August flow
- Flow depth less than 5 feet
- Flow velocity less than 2 ft/sec

Refer to the BiOp for additional information on the SWH performance standards (USFWS 2003, pg 193). BiOp SWH goals defined for each segment are summarized in Table 1.

Table 1.

BiOp Shallow Water Habitat Goals								
BiOp Segment	RM Range (miles)	BiOp CWCP SWH Base Acres (ac/mi) Current --- Deficit		Year				
				2004	2005	2010	2015	2020
Sioux City - Segment 11 Ponca to Sioux City	753 - 735	2	28	40	50	151	302	504
Omaha - Segment 12 Sioux City to Platte River	735 - 595.5	1.8	28.2	315	393	1180	2360	3934
Nebraska City/St. Joe -Segment 13 Platte River to Kansas City, MO	595.5 - 367.5	4.6	25.4	463	579	1737	3475	5791
Kansas/Boonville -Segment 14 Kansas City, MO to Osage River	367.5 - 130.4	4.6	25.4	482	602	1807	3613	6022
Osage to Mouth - Segment 15	130.4 - 0.0	5	25	265	331	994	1987	3312
Total By Segment				1,565	1,956	5,869	11,738	19,564
Compare to BiOp Target (Table 9, pg 190)				1,700	2,000	5,870	11,739	19,565

Kansas City District - Hamp Program.

HAMP Surveys

The Habitat Assessment and Monitoring Program (HAMP) constitutes a major comprehensive effort to document and assess ongoing programs of habitat creation on the Missouri River. The Kansas City District Hamp Program has collected survey data at portions of twenty four bends between 2006 and 2009. No data was collected in 2010. Because engineering (structure) modifications were inconsistently applied across Missouri River segments and bends, the bend rather than specific structural modifications was chosen as the experimental unit. Segments were stratified into bends (approximating the 25th and 75th percentiles in bend radius) to capture the range of river geomorphologies and flow patterns likely to influence the effects of modifications on biological response. The data collected at each bend included hydrographic, ADCP, and sediment samples.

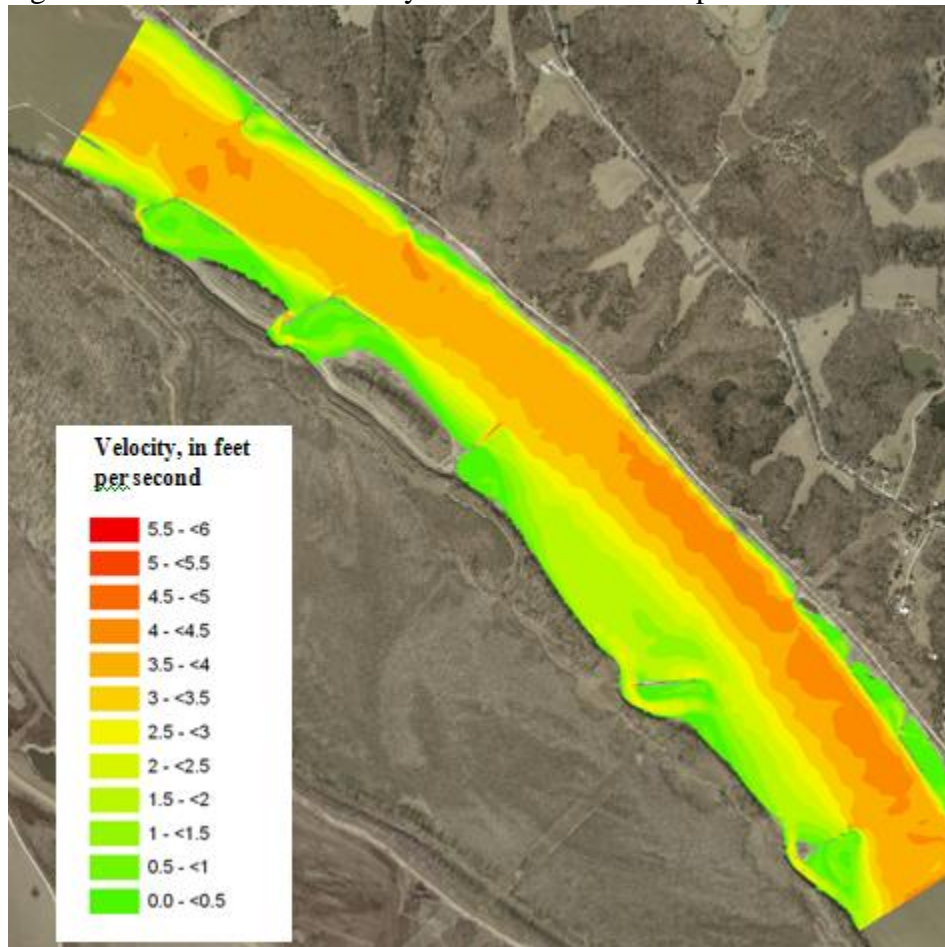
Parameters for the 24 bends included within the Kansas City District HAMP survey program are summarized in Table below:

2008 Kansas City HAMP Bend Survey Location

Bend Number	Bend Name	Bend Type	Down stream River Mile	Up stream River Mile	Length (miles)
10	Creve Coeur Bend	75%	28.4	31.8	3.4
17	Doziers Bend	75%	45.4	48.6	3.2
26	Washington Bend	75%	67.0	69.8	2.8
33	Pinckney Bend	25%	82.9	85.5	2.6
50	Chamois Bend	25%	115.9	119.1	3.2
54	Isbell Bends	25%	125.2	127.3	2.1
69	Eureka Bend	25%	159.1	162.4	3.3
75	Searcys Bend	25%	178.5	180.5	2.0
77	Rocheport Bends	75%	181.8	183.5	1.7
87	Slaughterhouse Bend	75%	203.8	205.6	1.8
89	Robinson Bends	75%	207.2	209.3	2.1
97	Wilhoite Bend	25%	232.5	234.5	2.0
104	Lower Miami Bend	25%	257.3	260.2	2.9
110	Malta Bend	25%	271.7	274.0	2.3
119	Baltimore Bend	75%	301.3	304.4	3.1
125	Sni Bends	75%	319.6	321.1	1.5
127	Camden Bend	25%	323.7	327.1	3.4
129	Fishing River Bend	75%	332.3	335.3	3.0
155	Upper Iatan Bend	75%	409.8	412.1	2.3
159	Rushville Bend	75%	425.3	428.8	3.5
163	Kenmore Bend	75%	435.2	438.8	3.6
171	Dallas Bends	25%	464.5	467.0	2.5
179	Tarkio Bend	25%	480.6	483.4	2.8
185	Nemaha Bends	25%	492.4	494.4	2.0
Total					45.8

2-D Model and Field data:

Biops requirements for SWH are depth less than 5 feet and velocity less than 2 ft/second. Velocity distribution along the Missouri River may be evaluated with either a multi-dimensional computation model or with physical field data collected with an Acoustic Doppler Current Profiler (ADCP). Only one HAMP bend, at Rocheport has the two-dimensional model. This model was constructed by the U.S. Geological Survey Missouri Water Science Center in support of the Kansas City District of U.S. Army the Corps of Engineers. Four material types are identified in the model; main channel, banks, sand and debris bars, and dikes. Figure below shows the velocity distribution at Rocheport:



HAMP Bends Acreage Analysis

At 15 bends shallow water habitat acreage, water surface elevation and depth distribution were computed.

In order to estimate shallow water habitat acreage, the August 50% exceedance flow is required. Analysis for those 15 bends was performed to evaluate shallow water habitat acreage and prepare depth shaded maps for the 50% exceedance August flow duration. Additional flows, (relevant flows to CRP and +5 CRP) were also analyzed in order to develop shallow water habitat duration curves at each bend.

The BiOp SWH definition also has a requirement for depth less than 5 ft. from HAMP data the approximate area of depth less than 5 feet was determined for each site. HAMP data was evaluated to determine the August 50% exceedance flow average SWH for each bend. Results from this analysis are illustrated in Figure below:

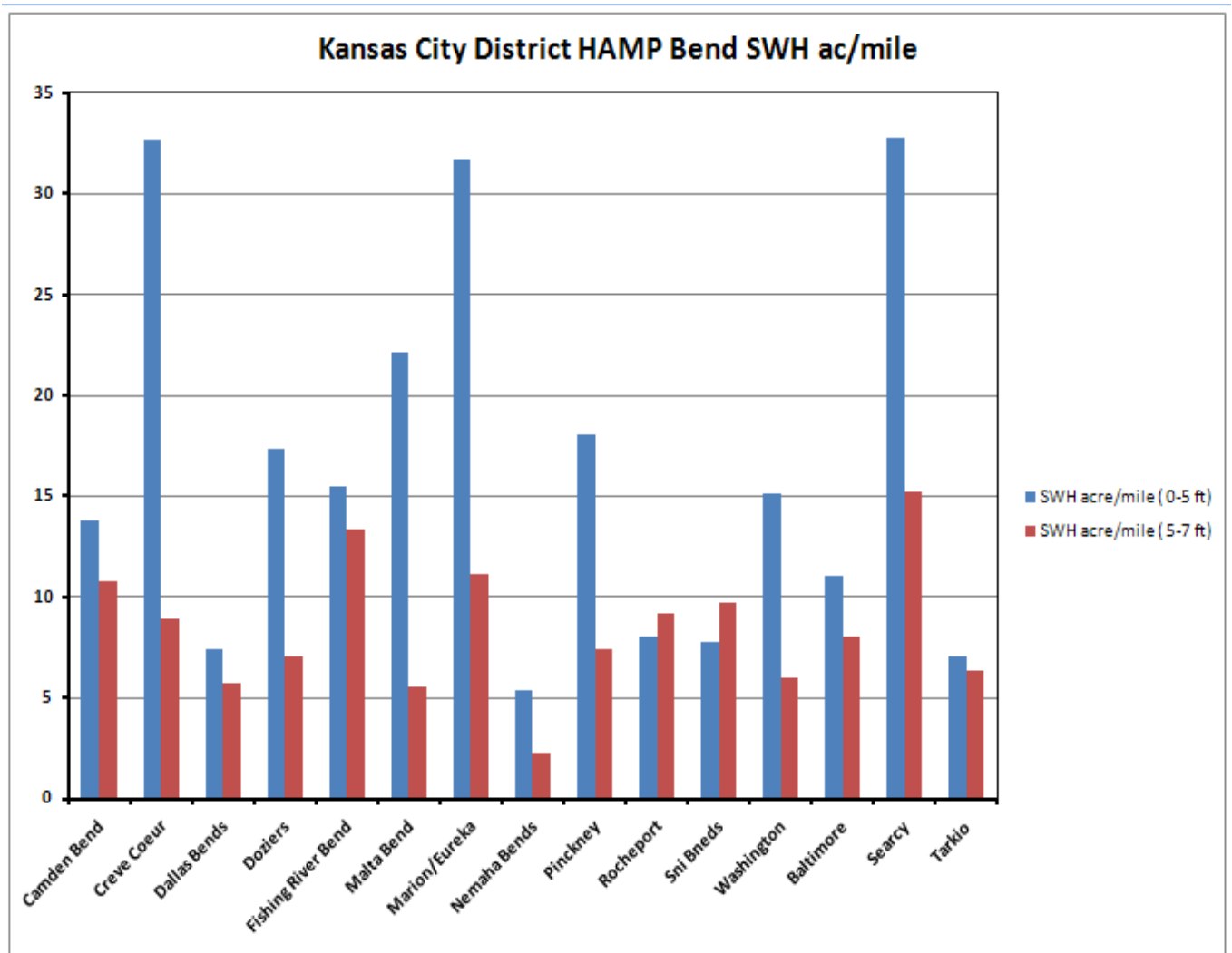


Figure below shows the depth distribution for August 50% exceedance flow at 15 HAMP bends:

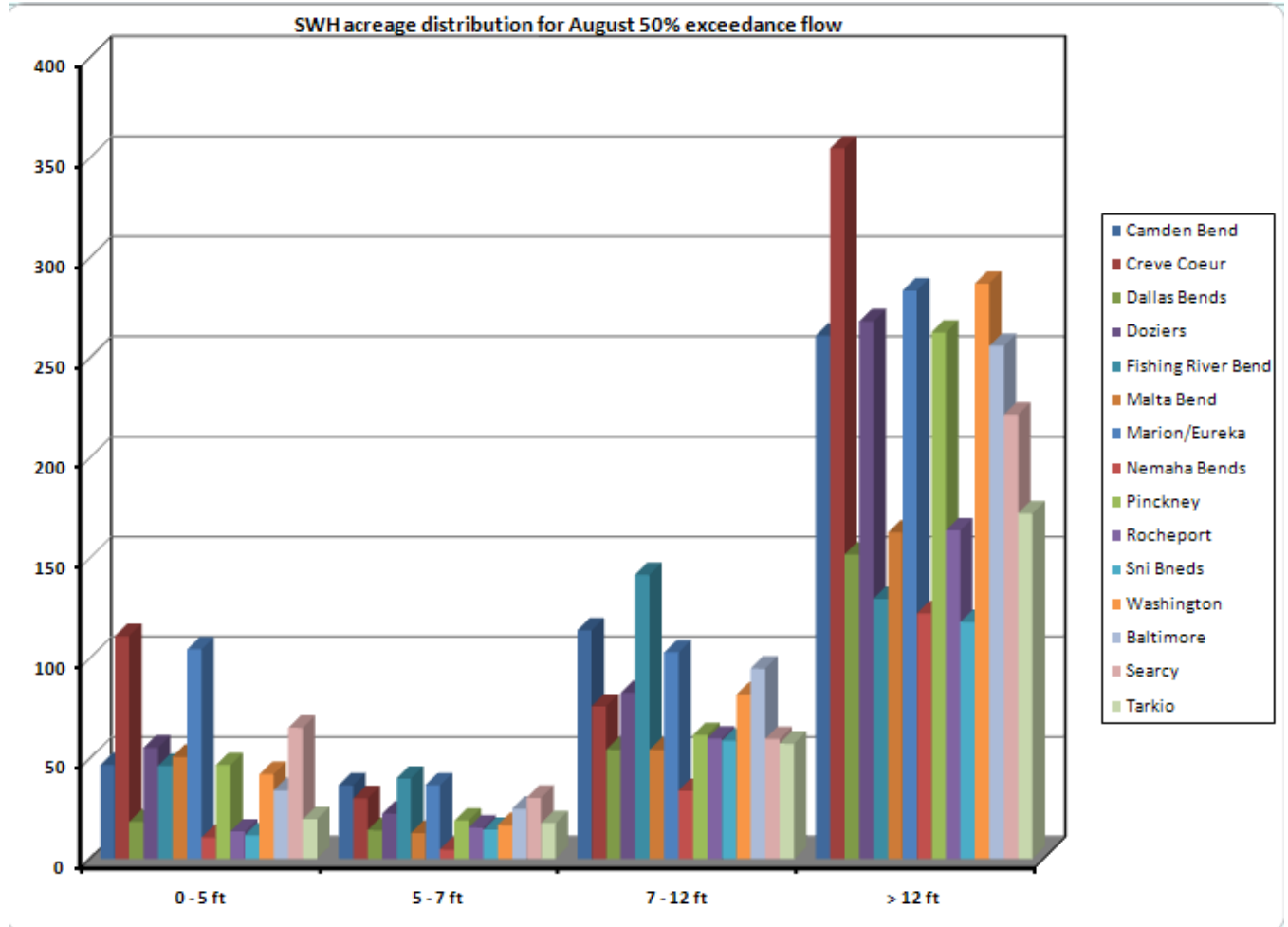
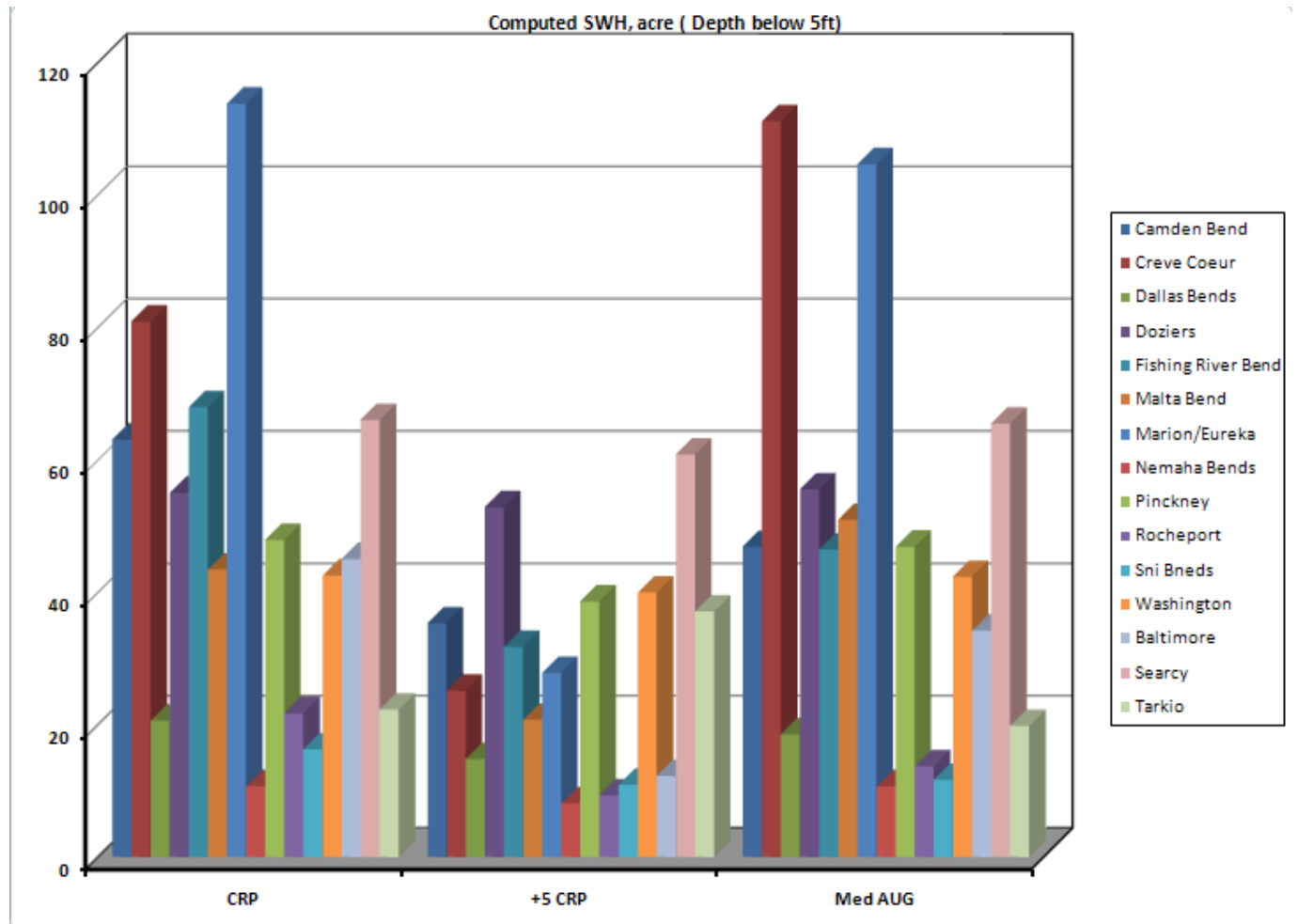


Figure below shows the SWH (0-5 feet deep) acreage difference for 3 different flows at CRP, +5 CRP and Median August:



Kansas City District Construction Activities.

The BSNP consists mainly of revetments along the outside of bends and transverse dikes along the inside of bends to force the river into a single active channel that is self-maintaining.

Shallow water habitat creation may be restored through flow management, channel widening, side channel chutes, manipulation of existing aquatic habitat or combination thereof.

Channel widening is accomplished by modifying the configuration of some of the roughly 7,000 rock and piling structures that comprise the BSNP. Modification includes notching, extending, raising and lowering the structures to effect changes to the existing aquatic habitat and/or erosion of the high bank. Notching was begun as early as 1975 in an effort to halt the accretion process that was narrowing the top width of the river and in an effort to improve the aquatic habitat of the river. Depending on the size and location of a notch, the flow can be used to erode the bank and increase diversity upstream and downstream of a notch or, if bank line erosion cannot be tolerated, the flow can be used to only increase diversity. Recent notches are in general wider, deeper, and placed closer to the bank than those from past years. A notch cut to -4 CRP will have some flow through the notch up to 95% of the time, greatly increasing the percent time of flow occurs across a structure.

A particular notch can be categorized as either a bank notch, a dike notch or a revetment notch. The SWH acreage associated with each activity is described in below.

Bank Notching:

Bank notching refers to the action of notching the banks in order to erode the banks and increase river's top width and creation of shallow water habitat. These are typically 75' notches excavated to -5 CRP constructed entirely landward of the high bank. These notches are constructed in straight out dikes or L-head dikes using land-based equipment.

Bank notches have numerous immediate and long term effects. The immediate effects include the creation of a secondary channel adjacent to the high bank as the water enters the upstream most notch and flows along the bank through the downstream bank notches. Deposition will occur riverward of the secondary channel resulting in sandbar formation and shallowing of the area between the dikes. The resulting habitat has greater depth and velocity variation than the pre-notch condition. The long-term effects are fairly rapid erosion of the high bank and widening of the top-width of the river. Depending on the size and location of a notch, the flow can be used to erode the bank and increase diversity upstream and downstream of a notch or, if bank line erosion cannot be tolerated, the flow can be used to only increase diversity. In general, the larger the notch and the closer the notch is located to the bank, the more the adjacent bank will erode and the more diversity will increase in the general area. Based on analysis of past and current bank notching efforts, one bank notch will create between 4 and 6 acres of diverse shallow water habitat.

A summary of bank notches constructed with Kansas City District is provided below:

Bank Notches Projects Summary				4	6	
Site	State	River Miles	Number of Bank Notches	Min acres	Max acres	Year
Baltimore Bend	MO	299.400 - 296.700	8	32	48	2004
Benedictine Bottoms	KS	425.8 - 428.2	9	36	54	2004
Diana Bend	MO	187 - 187.2	2	8	12	2004
Eagle Bluffs	MO	177.1 - 172.2	12	48	72	2004
Franklin Island	MO	193.45 - 192.2	3	12	18	2004
Grand Pass	KS	271.1 - 268.8	5	20	30	2004
Marion Bend	KS	160.8 - 161.5	9	36	54	2004
Monkey Mountain	MO	465.2 - 464.7	5	20	30	2004
Overton	MO	179.80 - 183.7	16	64	96	2003
Smokey Waters	MO	130.8 - 132.7	5	20	30	2004
Wolf Creek	MO	477 - 480	11	44	66	2006
Worthwine Island	KS	456.5 - 457	11	44	66	2004
Total			96	384	576	
Total SWH Acres			384 to 576			

Constructed Bank Notches in Kansas city District

Year	Number of Bank Notches			Min acres	Max acres
2003		16		64	96
Overton RIM 179.8					
2004		69		300	432
Monkey Mountain				20	30
Worthwine Island				44	66
Benedictine Bottoms				36	36
Baltimore Bend				32	48
Grand Pass				20	30
Franklin Island				36	54
Diana Bend				8	12
Eagle Bluffs				48	72
Marion Bottoms				36	54
Smokey Waters				20	30
2005		0		0	0
2006		11		44	66
Wolf Creek					
2007		0		0	0
Total		96		384	576

Dike Notching:

Dikes were constructed as part of Bank Stabilization and Navigation Project (BSNP). Dikes modification refers to notch the dike in order to channel widening by redirecting flow in the near bank erosion and causing deposition within the modified structure.

These notches range in width between 50' to 100' and are excavated to either -4 or -5 CRP.

These notches are excavated entirely riverward of the high bank between the high bank and no more than half-way out on the dike.

These notches improve the depth and velocity diversity upstream and downstream of the dike by allowing a portion of the river's flow to flow within the dike field. As the flow spreads out downstream and riverward of a notch, the velocity slows down and creating a high degree of velocity variability. In addition to the increased velocity diversity, a deep scour hole will form immediately downstream of a notch and deposition will generally occur further downstream and riverward from the notch increasing the depth diversity. The result is an area with a high degree of depth and velocity diversity upstream and downstream of the notch.

Based on analysis of past and current notching, a 50' dike notch will create one acre of diverse shallow water habitat and a 100' notch will create two acres of diverse shallow water habitat.

A summary of dike modifications constructed within Kansas City District is provided below:

Dike Notches Projects Summary					Shallow Water Habitat Area		
Year	Number of Notches	Minimum Width	Average Width	Maximum Width	Min	Ave	Max
		ft	ft	ft	acre	acre	acre
2000	57	20	79	200	22.8	90.14	228
2001	88	30	74	145	52.8	130.18	255.2
2002	127	20	64	378	50.8	163.5	960.12
2003	66	30	86	278	39.6	112.88	366.96
2004	460	50	62	200	460	570.4	1840
2005	32	50	52	60	32	33.28	38.4
2006							
Total	830				658	1100	3689
Total SWH Acres		658 to 3689					

Revetment Notching:

Revetment constructions were part of Bank Stabilization and Navigation Projects (BSNP).

Revetment notches are cut in stone fill revetments at locations where a slack water pool is separated from the main channel by a stone fill revetment. Without notches in the revetment, these aquatic areas are poorly connected to the main channel at normal summer flows, and therefore have little to no flow, and no velocity diversity. These notches range in width between 50' to 100' and were excavated to either -4 or -5 CRP. In most cases notches were cut at the upstream and downstream end of the pool to maximize the effects of the notches.

A revetment notch increases the connectivity of the slack water pool with the main channel. The increased connectivity increases the flow in the slack water area which increases the velocity diversity and increases the depth diversity of the area.

Based on analysis of past and current revetment notching efforts, a 50' revetment notch will create one acre of diverse shallow water habitat and a 100' revetment notch will create two acres of diverse shallow water habitat.

A summary of revetment notches constructed within Kansas City District is provided below:

Revetment Notches Projects Summary					Shallow Water Habitat Area		
Year	Number of Notches	Minimum Width	Average Width	Maximum Width	Min	Ave	Max
		ft	ft	ft	acre	acre	acre
2000	9	30	53	100	5.4	9.54	18
2001	30	30	76	100	18	45.72	60
2002	26	50	61	100	26	31.72	52
2003	20	50	75	100	20	30	40
2004	91	50	65	200	91	118.3	364
Total	176				160	235	534
Total SWH Acres		160 to 534					

Revetment Chutes

channels are trenches excavated immediately landward of a stone fill revetment. The trenches are connected to the river by notches in the adjacent revetment. Revetment chutes have at least a 50' bottom width and range between 1000' and 2400' in length.

By excavating the overbank, revetment chutes have the immediate effect of increasing the amount of available shallow aquatic habitat.

It is also expected that the aquatic habitat in the dike field across the river from the revetment chute will experience some deposition due to the redirection of water out of the main channel.

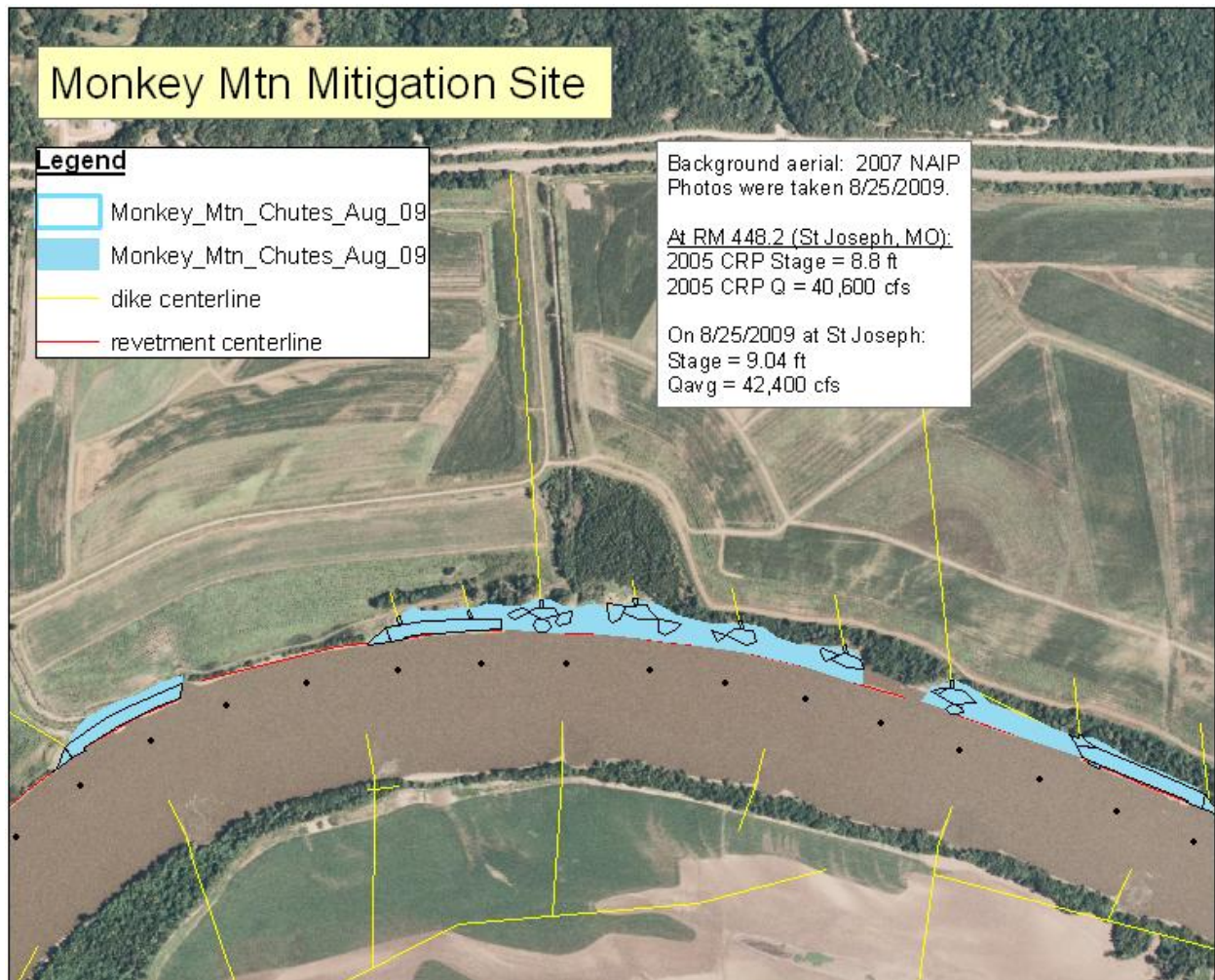
A summary of revetment chutes constructed within Kansas City District is provided below:

Revetment Chutes Projects Summary					
SITE	SWH_ID	RM	State	Area acre	Year
Benedictine Bottoms	Pilot A	424	KS	4	2004
Diana Bend	Pilot B	187	MO	1.24	2004
*Diana Bend	Pilot C	187	MO	1.24	2004
Franklin Island	Pilot A	194	MO	0.46	2004
*Fort Leavenworth	Pilot A	404	KS	0.11	2002
Monkey Mountain	Pilot A	466	KS	1.00	2004
Monkey Mountain	Pilot B	465	KS	0.84	2004
Monkey Mountain	Pilot C	465	KS	0.95	2004
Liberty Bend	Pilot A	351	MO	1.74	2004
*Overton	Pilot C	183	MO	0.24	2003
*Tate Island	Pilot C	112	MO	0.31	2003
*Tate Island	Pilot B	112	MO	0.09	2003
*Tate Island	Pilot A	113	MO	0.26	2003
*Weston Bend	Pilot B	403	KS	1.40	2004
*Weston Bend	Pilot A	403	KS	1.77	2004
Wolf Creek	Revetment Chute A	481	KS	5.35	2006
Worthwine Island	Pilot A	459	MO	4.17	2004
Total				19.79	
Total SWH Acres		19.79			
*These projects silted in and no longer function.					

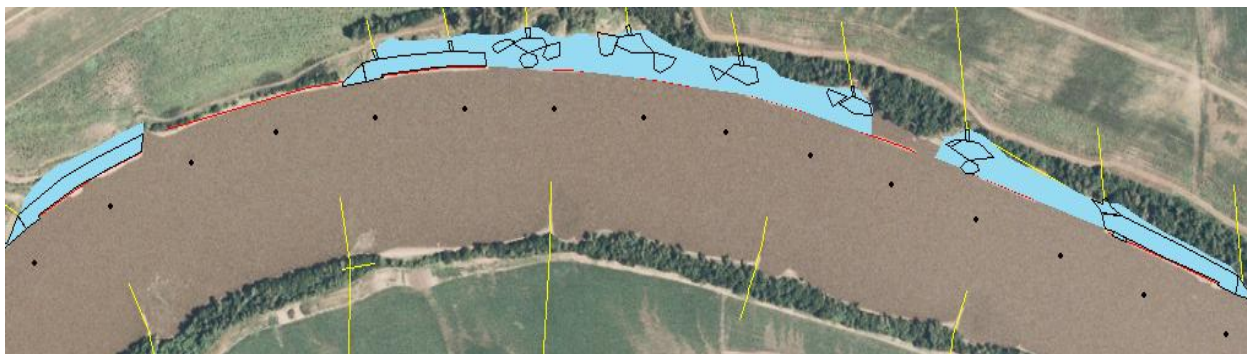
In August 2009 a field review of SWH sites within Kansas City District was made to evaluate and monitor the function of Missouri River chutes. 8 sites were visually inspected and bank line points were collected by running a boat along the bank line. The bank line was digitized in GIS by assuming the collected points were 10 ft riverward of the actual chute banks. Field measurements compared to GPS points verified this to be a good approximation. Also few cross section points were collected. A summary of Revetment chute comparison is listed below:

				Shallow Water Habitat Area		
Revetment Chute Projects Comparison Summary				Design	Aug 2009/ Projected	
SITE	SWH_ID	RM	State	Area acre	Area acre	Difference acre
Monkey Mountain	Pilot C	464.5	KS	0.95	5.85	4.90
Monkey Mountain	Pilot B	465.4	KS	0.84	12.00	11.16
Monkey Mountain	Pilot A	465.8	KS	1.00	2.70	1.70
Wolf Creek	Revetment Chute A	481	KS	5.35	13.95	8.60
Worthwine Island	Revetment Chute	458	MO	4.16	5.78	1.62
*Benedictine Bottoms	Pilot A	424	KS	4	4.46	0.41
*Diana Bend	Pilot B	187	MO	1.24	1.34	0.10
*Franklin Island	Pilot A	194	MO	0.46	0.54	0.08
*Liberty Bend	Pilot A	351	MO	1.74	2.41	0.67
Total				19.79	49.02	29.23
Total SWH Acres		20 to 49				
*Maximum projected area, assuming double of the constructed width.						

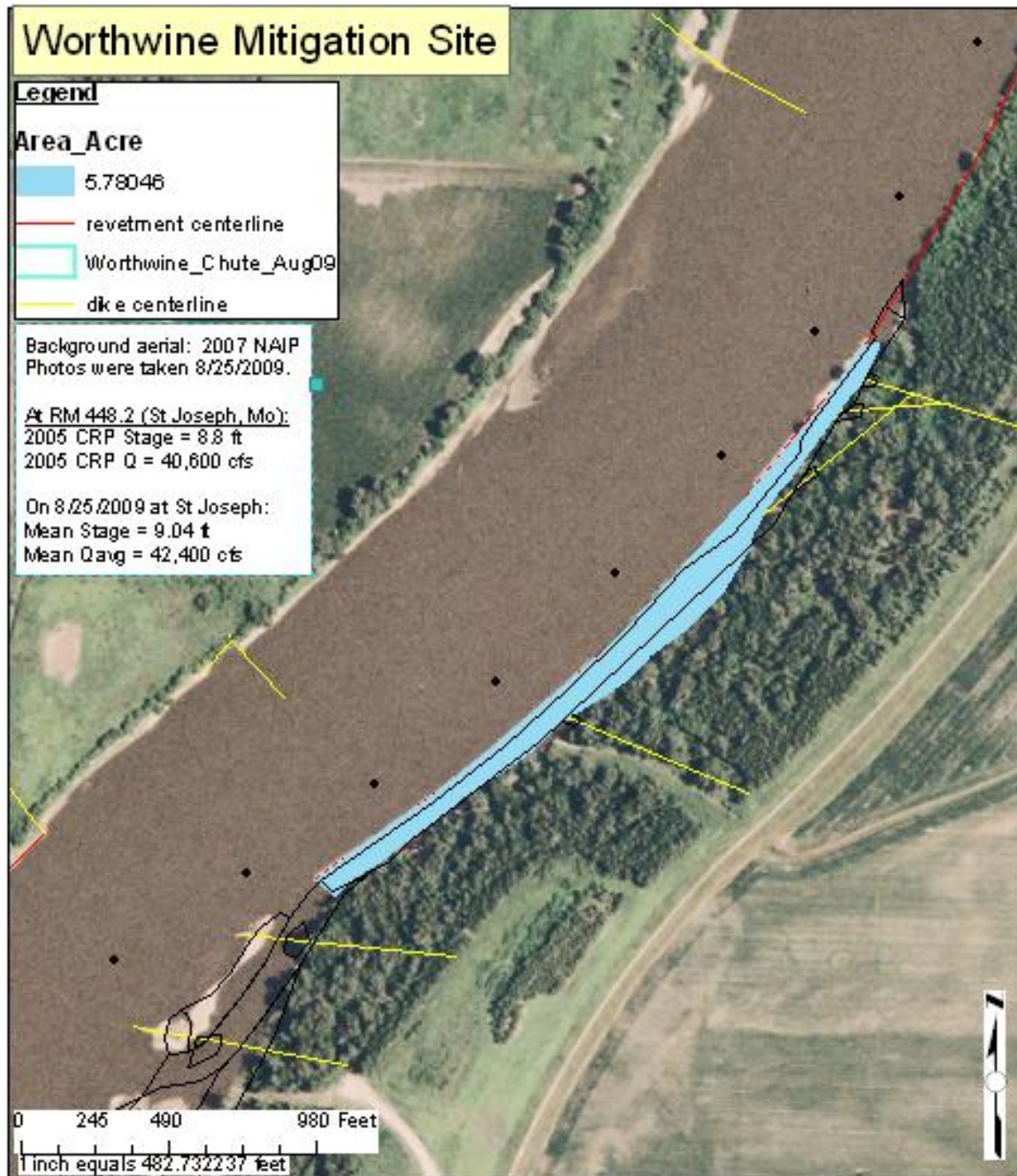
Monkey Mountain Revetment Chutes top width comparison (zoomed out view)



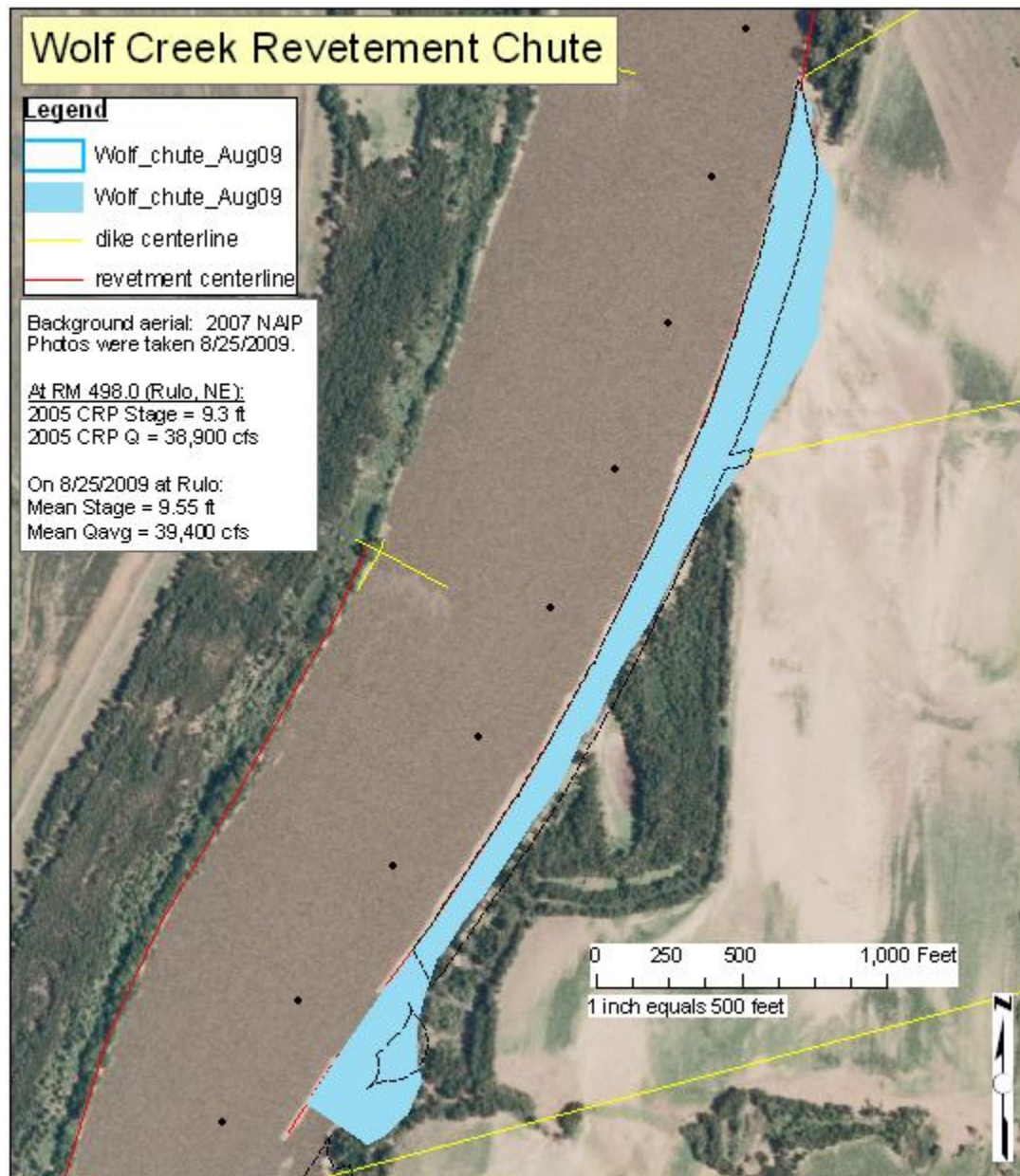
Monkey Mountain Revetment Chutes top width comparison (zoomed view)



Worthwine Revetment Chute top width comparison



Wolf Creek Revetment Chute top width comparison (zoomed out view)



Chute

Chutes are trenches excavated entirely within the overbank and connected to the river at the entrance and the exit. The overall goal for creation chutes, as a component of the mitigation program, is to develop fish and wildlife habitat. During normal summer flows, the flow in the chutes will be shallow and slow with a high degree of diversity. The chute bottom will be very dynamic with a sandy substrait.

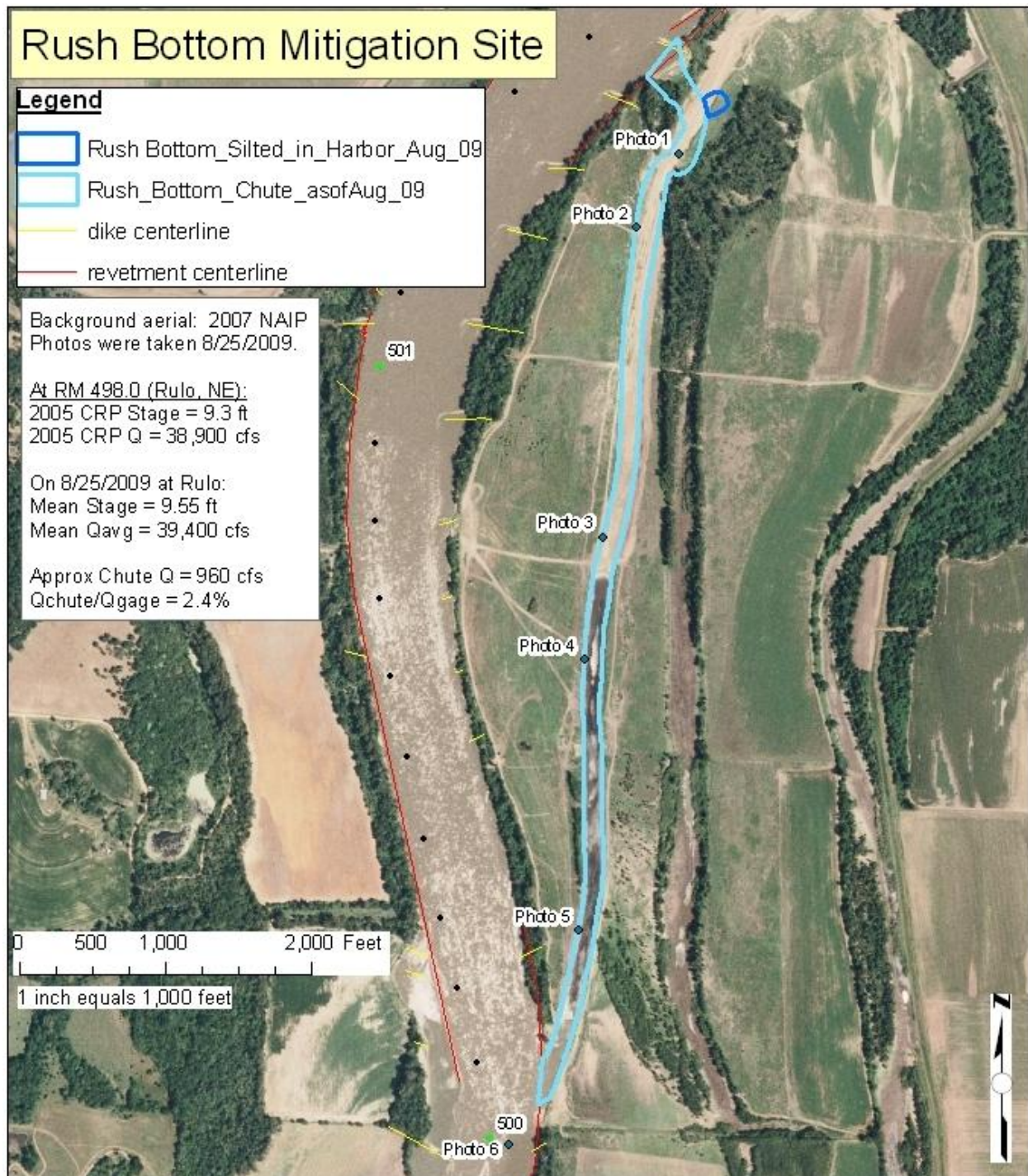
Chutes are desired to create a more diverse riverine habitat by eroding the existing bank to create shallow water habitat.

Flows through the chute are controlled by new rock structures placed within the chute. Chute alignment and the ratio of the chute length to the main channel length is a good indicator of chute dynamics and sustainability. Due to sediment load it is critical to maintain minimum chute flow velocities to prevent chute aggradation and possible disconnection from the river. A summary of chutes constructed within Kansas City District is provided below:

Chute Projects Summary					
SITE	SWH_ID	State	RM	Constructed Area	Year
				acre	
Diana Bend	Chute A	MO	187.4	1.25	2004
*Franklin Island	Chute 1	MO	194.3	0.965	2004
*Franklin Island	Chute 2	MO	194.15	1.343	2004
*Franklin Island	Chute 3	MO	194	1.089	2004
*Franklin Island	Chute 4	MO	193.9	1.284	2004
*Franklin Island	Chute 5	MO	193.8	1.384	2004
*Franklin Island	Chute 6	MO	193.65	1.296	2004
Jameson Island	Jameson Island Chute	MO	213	37.400	2007
Lisbon	Lisbon Weir	MO	218.1	0.106	2004
Lisbon	Lisbon Chute	MO	218.1	30	2004
Overton	Chute 1	MO	183.1	1.048	2003
Overton	Chute 2	MO	182.9	1.728	2003
Overton	Overton North Chute	MO	187.1	12.663	2003
Overton South	Tadpole Island Chute	MO	179	30.420	2006
Overton South	Tadpole Island Chute Entrance	MO	180.4	0.516	2006
Rush Bottoms	Rush Bottoms Chute	MO	501	12.046	2008
Smokey Waters	Chute A	MO	132.9	5.667	2004
Worthwine Island	Worthwine Chute	MO	458	18.363	2006
Total				151.2	
Total SWH Acreage				151.2	
*These projects silted in and no longer function.					

				Shallow Water Habitat Area		
Chute Projects Comparison Summary				Design	Aug 2009/ Projected	
				Area	Area	Difference
SITE	SWH_ID	State	RM	acre	acre	acre
Rush Bottoms	Rush Bottoms Chute	MO	501	12.04	24.35	12.31
Worthwine Island	Worthwine Chute	MO	458	18.36	23.13	4.77
Tadpole	Tadpole Chute	MO	179	30.41	56.74	26.33
Jameson Island	Jameson Island Chute	MO	213	37.400	45.83	8.43
Overton North	Overton north chute	MO	187.1	12.66	30.96	18.30
*Diana Bend	Chute A	MO	187.4	1.25	4.29	3.04
*Lisbon	Lisbon Chute	MO	218.1	30	64.75	34.75
*Overton	Chute 1	MO	183.1	1.048	5.21	4.16
*Overton	Chute 2	MO	182.9	1.728	7.36	5.63
*Overton South	Tadpole Island Chute Entrance	MO	180.4	0.516	1.84	1.32
*Smokey Waters	Chute A	MO	132.9	5.667	17.17	11.50
Total				151.1	281.6	130.54
Total SWH Acres 151 to 282						
*Maximum projected area, assuming width equals to 275 feet.						

Rush Bottom chute in August 2009

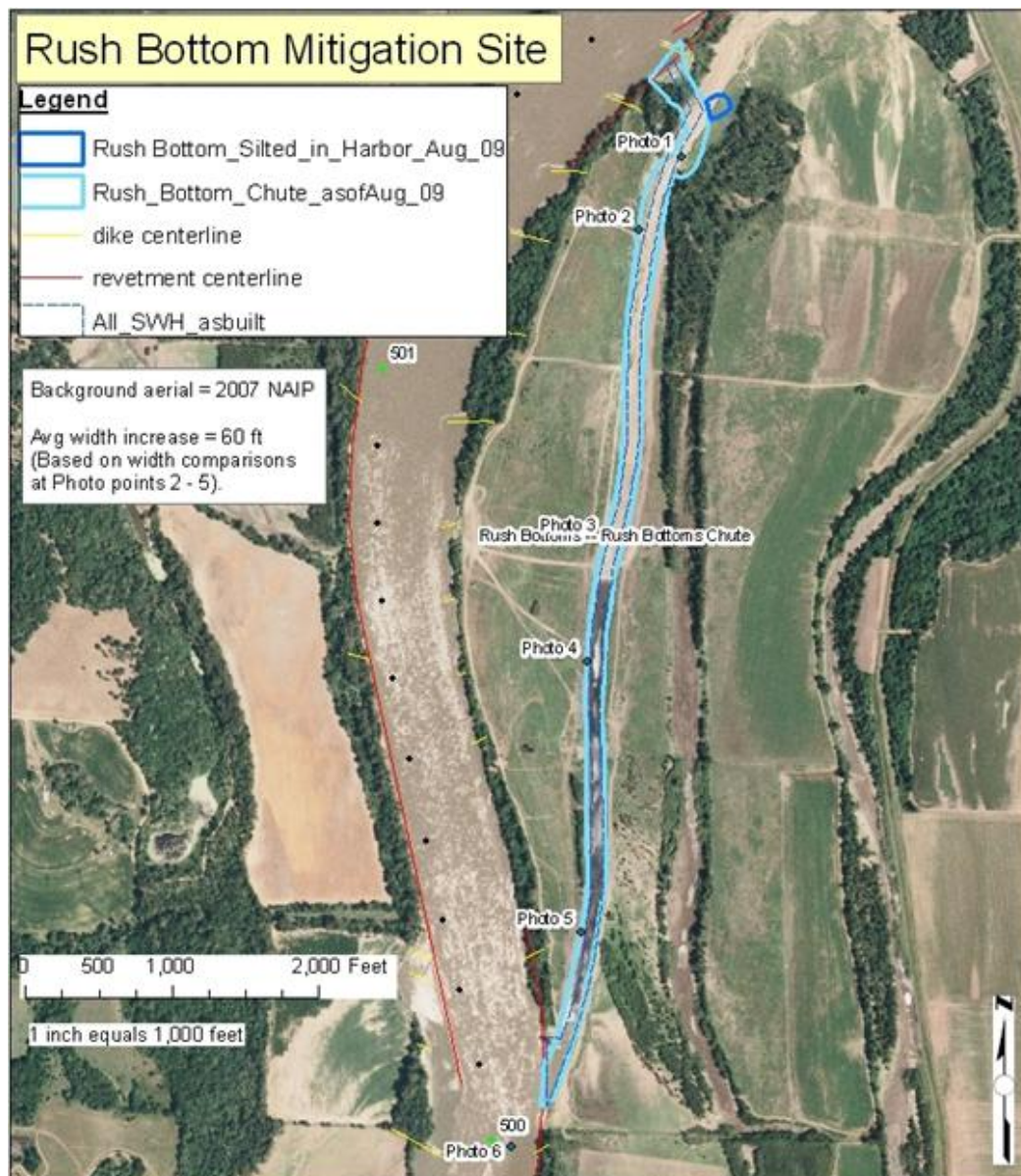


Cross section at Rush Bottom and average measured depth and velocity:

Incremental distance (ft)	Distance from West Bank (ft) x	Measured Depth (ft) y	Measured Velocity (ft/s) V
0	0	0	0
14	14	-6	1.4
30	44	-7.5	2.1
40	84	-7.5	1.7
24	108	-3.7	0.8
5	113	0	0

sum: 113

Rush Bottom top width comparison (zoomed out view)



Rush bottom designed width was approximately 70 ft, and in August 2009 inspection average width increased by 60 ft.



Location Photo #	Width of old chute (ft)	Width of Aug09 chute (ft)	Width Increase (ft)
2	72	156	84
3	71	129	58
4	71	132	61
5	71	106	35

Avg Width Incr: 60 ft

Rush Bottom top width comparison (zoomed view)



Tadpole Chute top width comparison (zoomed out view)



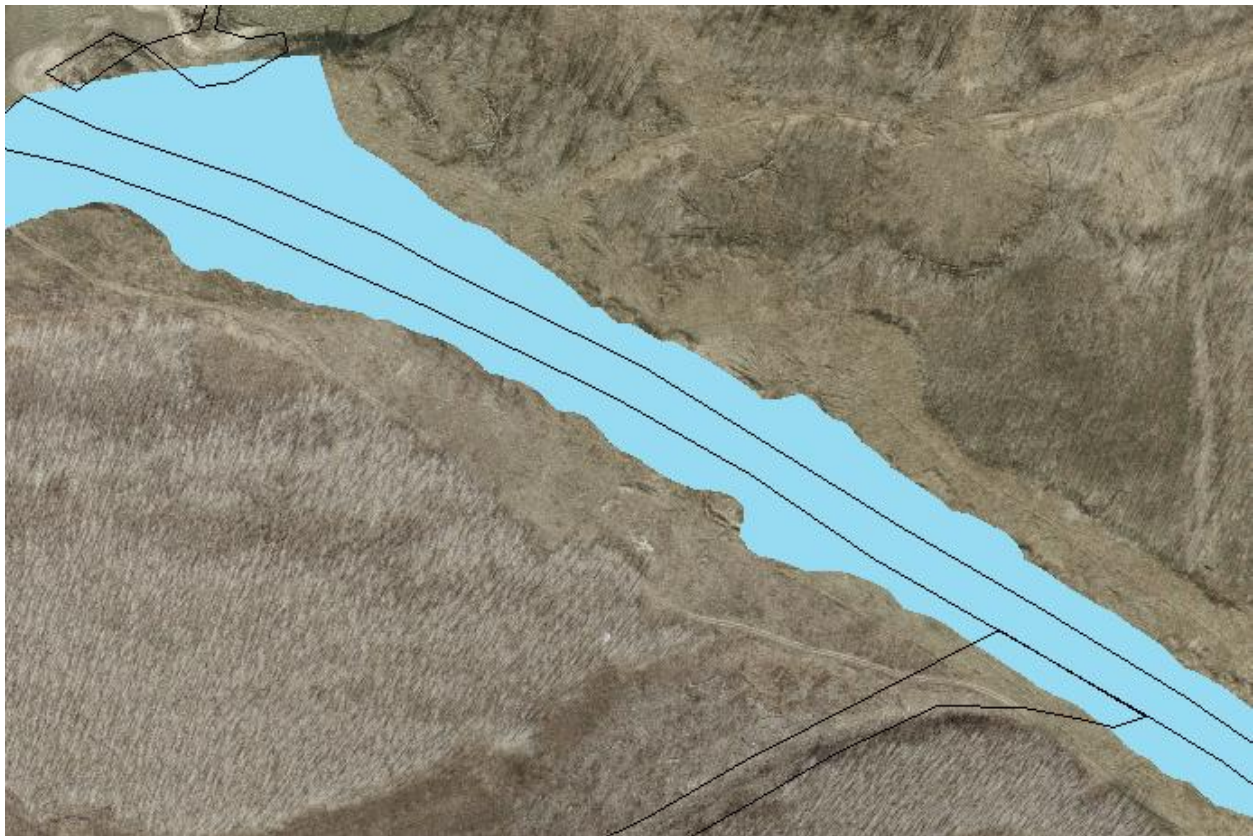
Tadpole Chute top width comparison (zoomed view)



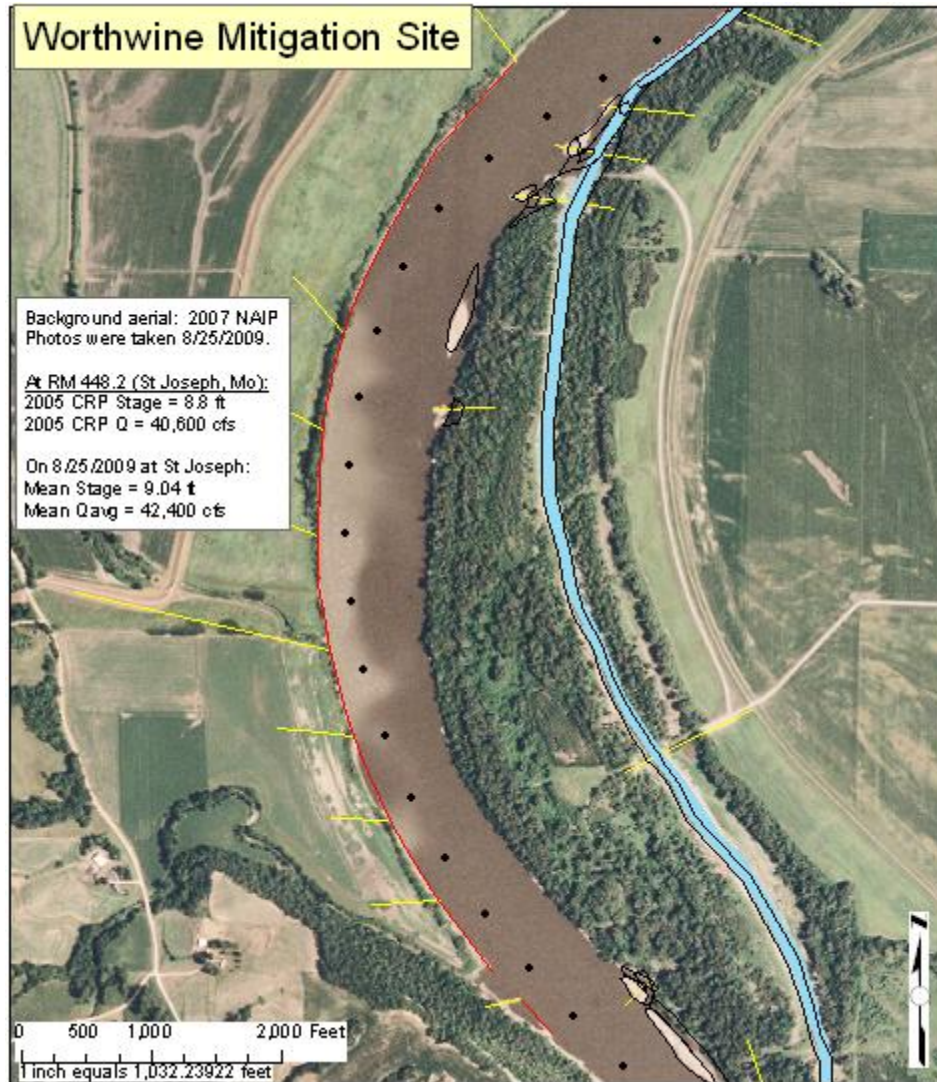
Overton North chute top width comparison (zoomed out view)



Overton North chute top width comparison (zoomed view)



Worthwine chute top width comparison (zoomed out view)



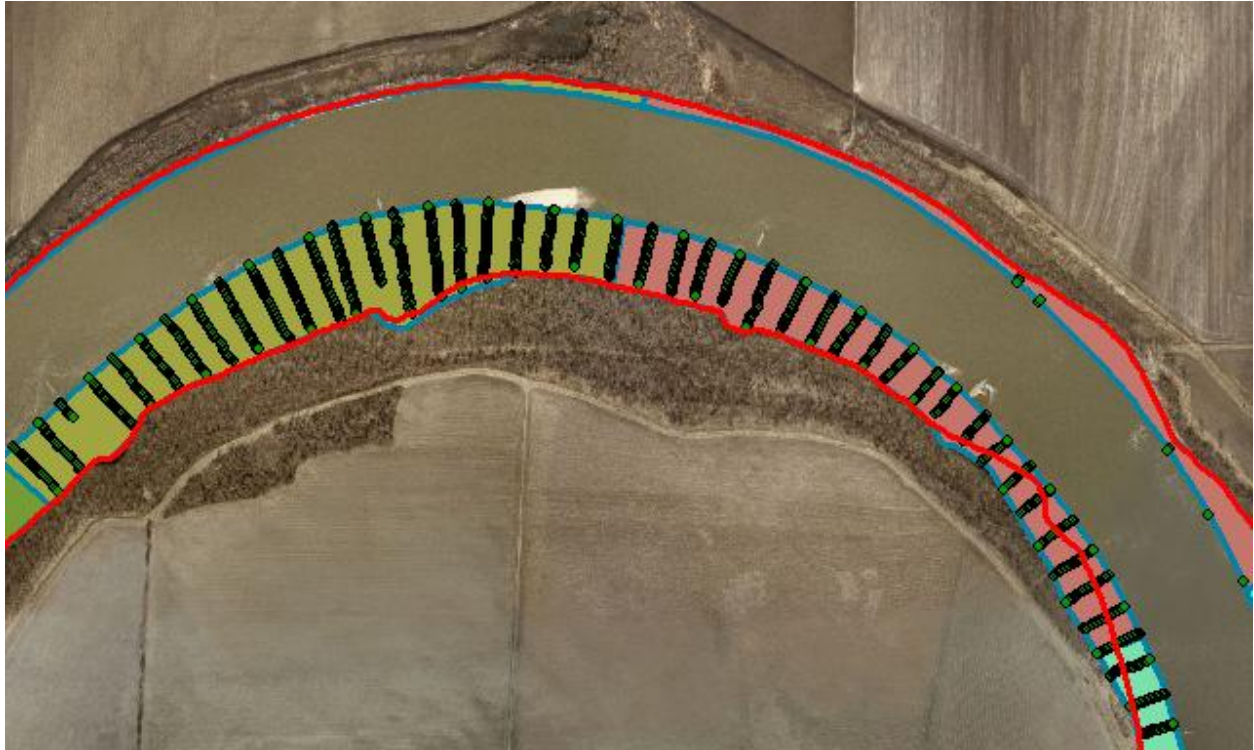
Worthwine chute top width comparison (zoomed view)



Kansas City District Bathymetric Survey Evaluation

2009 Hydro survey data points were used to count shallow water habitat acreage. By using GIS, the area between Rectified Channel Line (RCL) and river bank were computed. The number of 2009 survey points intersecting the polygons between RCL and bank line were counted. In order to determine the extent of shallow water habitat, the August 50% flow exceedance water level is required. Median August flow (the %50 exceedance discharge from the August flow duration curve)(USFWS,2003) were associated to each river mile. Based on Median August, the depth for each point inside the polygon was calculated. For each river mile, the depth distribution was computed. Since the flow within the Kansas City District during the time of the survey was low, at some locations the hydro survey points don't cover the whole area and some adjustments were made.

Figure below shows the polygons between RCL and river bank and 2009 Hydro survey point inside the polygons at RM= 285, 286.



After 2009 hydro survey points thinning process, the survey points thinned to exact every 10 ft. cross section surveys are every 250 ft. by knowing the spacing between the points and cross sections, the acreage area for each depth was calculated.

RM	Median Aug	Depth Estimates(Aerial Photo)					Range of Depth - Measured (area, acres)						S u r v	Total Depth (Measured+Aerial Photo)						
		1 to 2 ft	3 to 4 ft	5 to 7 ft	8 to 10 ft	Total Estimated	1 to 2 ft	3 to 4 ft	5 to 7 ft	8 to 10 ft	11 to 15 ft	16' or greater		1 to 2 ft	3 to 4 ft	5 to 7 ft	8 to 10 ft	11 to 15 ft	16' or greater	Total Drawing
59	454.41	7.70	12.48	4.78	0.84	25.80	0.52	3.04	12.74	15.38	9.13	4.48	#	8.22	15.52	17.52	16.22	9.13	4.48	41.26
60	455.43	9.30	15.03	5.73	4.74	34.80	1.09	2.18	8.21	11.99	11.42	5.85	#	10.39	17.21	13.94	16.73	11.42	5.85	75.55
61	456.45	2.20	8.73	6.53	4.74	22.20	0.46	2.18	16.82	11.88	4.59	7.17	#	2.66	10.91	23.35	16.62	4.59	7.17	65.30
62	457.41	0.00	0.00	0.00	0.00	0.00	0.29	4.48	23.19	19.69	5.62	7.00	#	0.29	4.48	23.19	19.69	5.62	7.00	60.26
63	458.20	3.90	4.25	0.35	0.30	8.80	0.69	2.18	8.32	24.16	6.71	2.98	#	4.59	6.43	8.67	24.46	6.71	2.98	53.85
64	458.99	15.55	20.76	5.21	0.18	41.70	1.15	9.24	21.29	9.30	5.74	2.98	#	16.70	30.00	26.50	9.48	5.74	2.98	91.40
65	459.91	2.80	7.82	5.02	5.46	21.10	0.52	2.70	6.60	5.05	7.29	5.11	#	3.32	10.52	11.62	10.51	7.29	5.11	48.36
66	460.87	3.15	4.27	1.12	3.06	11.60	0.52	1.84	5.17	7.46	14.75	11.54	#	3.67	6.11	6.29	10.52	14.75	11.54	52.86
119	507.92	1.60	1.93	0.33	0.24	4.10	0.23	0.98	4.19	18.82	12.97	6.60	#	1.83	2.91	4.52	19.06	12.97	6.60	9.25
120	508.70	1.50	6.40	4.90	4.80	17.60	0.46	0.69	5.34	10.85	14.06	9.18	#	1.96	7.09	10.24	15.65	14.06	9.18	19.29
121	509.48	1.75	1.99	0.24	0.42	4.40	1.32	3.96	17.91	13.43	11.99	5.85	#	3.07	5.95	18.15	13.85	11.99	5.85	27.17
122	510.30	4.80	10.25	5.45	6.00	26.50	0.23	0.86	2.47	6.60	7.23	6.54	#	5.03	11.11	7.92	12.60	7.23	6.54	24.06
123	511.16	2.85	3.62	0.77	0.96	8.20	7.63	18.08	30.88	9.64	2.07	1.21	#	10.48	21.70	31.65	10.60	2.07	1.21	63.83
124	512.02	3.55	4.16	0.61	0.18	8.50	1.66	6.37	11.19	12.91	7.23	3.85	#	5.21	10.53	11.80	13.09	7.23	3.85	27.55
125	512.87	7.35	14.79	7.44	4.32	33.90	6.60	8.78	14.92	9.13	6.54	10.79	#	13.95	23.57	22.36	13.45	6.54	10.79	59.88
126	513.71	4.25	5.85	1.60	2.70	14.40	0.92	7.29	15.61	10.22	5.51	9.47	#	5.17	13.14	17.21	12.92	5.51	9.47	35.52
179	561.14	17.95	21.23	3.28	0.24	42.70	0.11	2.47	9.35	5.74	3.39	0.46	#	18.06	23.70	12.63	5.98	3.39	0.46	54.40
180	562.04	10.20	21.12	10.92	5.46	47.70	0.00	1.61	5.22	2.64	2.18	0.46	#	10.20	22.73	16.14	8.10	2.18	0.46	49.07
181	562.73	4.70	6.93	2.23	2.04	15.90	0.06	2.12	7.35	2.98	4.88	7.98	#	4.76	9.05	9.58	5.02	4.88	7.98	23.39
182	563.43	7.95	9.97	2.02	2.46	22.40	0.00	0.46	6.83	14.29	9.99	3.90	#	7.95	10.43	8.85	16.75	9.99	3.90	27.23
183	564.35	7.70	14.29	6.59	4.62	33.20	0.00	1.15	7.23	2.18	1.89	6.08	#	7.70	15.44	13.82	6.80	1.89	6.08	36.96
184	565.28	6.70	9.05	2.35	2.10	20.20	0.00	0.57	2.01	4.42	3.96	5.17	#	6.70	9.62	4.36	6.52	3.96	5.17	20.68
185	566.22	5.25	7.26	2.01	0.78	15.30	0.00	1.49	13.31	3.73	1.38	1.72	#	5.25	8.75	15.32	4.51	1.38	1.72	29.33
186	567.15	11.45	17.17	5.72	4.86	39.20	0.11	1.03	6.43	4.36	6.54	6.89	#	11.56	18.20	12.15	9.22	6.54	6.89	41.92
219	595.19	21.30	22.11	0.81	0.18	44.40	0.00	0.46	8.67	4.19	2.01	2.01	#	21.30	22.57	9.48	4.37	2.01	2.01	53.35
220	596.05	5.50	9.73	4.23	3.24	22.70	0.00	0.29	3.73	6.37	6.20	3.79	#	5.50	10.02	7.96	9.61	6.20	3.79	23.48
221	596.87	7.05	9.48	2.43	1.74	20.70	0.00	0.63	18.60	4.07	2.24	1.03	#	7.05	10.11	21.03	5.81	2.24	1.03	38.19
222	597.56	4.15	5.87	1.72	1.56	13.30	0.00	0.34	3.62	3.62	6.26	9.30	#	4.15	6.21	5.34	5.18	6.26	9.30	15.70
223	598.26	1.75	2.92	1.17	0.66	6.50	0.00	0.57	11.36	7.81	2.12	2.81	#	1.75	3.49	12.53	8.47	2.12	2.81	17.78
224	598.95	2.90	4.34	1.44	2.22	10.90	0.00	0.17	4.65	5.51	4.13	6.94	#	2.90	4.51	6.09	7.73	4.13	6.94	13.50
225	599.42	4.80	7.78	2.98	2.34	17.90	0.00	0.57	3.16	5.51	4.07	5.91	#	4.80	8.35	6.14	7.85	4.07	5.91	19.29
226	599.88	4.65	6.94	2.29	0.42	14.30	0.00	0.17	0.69	1.09	1.03	2.07	#	4.65	7.11	2.98	1.51	1.03	2.07	14.74

RM	Median Aug	Depth Estimates(Aerial Photo)					Range of Depth - Measured (area, acres)						S u r v	Total Depth (Measured+Aerial Photo)						
		1 to 2 ft	3 to 4 ft	5 to 7 ft	8 to 10 ft	Total Estimated	1 to 2 ft	3 to 4 ft	5 to 7 ft	8 to 10 ft	11 to 15 ft	16' or greater		1 to 2 ft	3 to 4 ft	5 to 7 ft	8 to 10 ft	11 to 15 ft	16' or greater	Total Drawing
279	644.91	7.45	12.75	5.30	5.40	30.90	0.00	1.95	2.47	2.58	1.09	0.63	#	7.45	14.70	7.77	7.98	1.09	0.63	29.92
280	645.75	8.10	10.51	2.41	2.58	23.60	0.00	0.06	1.78	2.24	1.03	0.63	#	8.10	10.57	4.19	4.82	1.03	0.63	22.86
281	646.59	13.80	19.91	6.11	1.68	41.50	0.40	2.30	0.92	0.17	0.40	2.35	#	14.20	22.21	7.03	1.85	0.40	2.35	43.44
282	647.43	2.45	4.76	2.31	1.98	11.50	0.11	1.26	3.16	5.97	3.27	1.55	#	2.56	6.02	5.47	7.95	3.27	1.55	14.05
283	648.28	1.80	7.42	5.62	5.46	20.30	0.11	8.26	8.32	2.24	1.95	0.69	#	1.91	15.68	13.94	7.70	1.95	0.69	31.54
284	649.30	3.70	8.37	4.67	6.36	23.10	0.11	0.98	6.03	11.59	4.07	4.59	#	3.81	9.35	10.70	17.95	4.07	4.59	23.86
285	650.40	2.55	3.26	0.71	0.48	7.00	0.46	8.84	18.48	8.95	0.75	0.98	#	3.01	12.10	19.19	9.43	0.75	0.98	34.30
286	651.65	0.00	0.00	0.00	0.00	0.00	0.00	1.61	22.04	29.33	4.65	3.10	#	0.00	1.61	22.04	29.33	4.65	3.10	23.65
349	706.30	2.40	2.75	0.35	0.30	5.80	0.00	2.87	5.57	6.71	2.07	3.56	#	2.40	5.62	5.92	7.01	2.07	3.56	13.94
350	707.23	3.15	5.42	2.27	0.96	11.80	0.06	1.61	6.54	2.75	0.86	0.46	#	3.21	7.03	8.81	3.71	0.86	0.46	19.05
351	708.10	9.80	18.36	8.56	3.48	40.20	0.00	0.23	0.80	0.69	2.53	0.23	#	9.80	18.59	9.36	4.17	2.53	0.23	37.75
352	708.51	1.00	1.35	0.35	0.60	3.30	0.00	0.23	0.80	1.38	1.89	0.00	#	1.00	1.58	1.15	1.98	1.89	0.00	3.73
353	708.92	2.35	4.04	1.69	0.72	8.80	0.00	0.34	3.16	1.43	0.57	0.40	#	2.35	4.38	4.85	2.15	0.57	0.40	11.58
354	709.50	6.55	8.48	1.93	0.54	17.50	0.00	0.34	0.92	3.62	1.72	1.78	#	6.55	8.82	2.85	4.16	1.72	1.78	18.22
355	710.78	5.85	6.58	0.73	0.24	13.40	0.06	0.63	3.62	3.67	1.43	1.78	#	5.91	7.21	4.35	3.91	1.43	1.78	17.46
356	712.05	6.40	7.39	0.99	1.02	15.80	0.00	0.17	2.18	2.07	1.55	4.94	#	6.40	7.56	3.17	3.09	1.55	4.94	17.13
379	729.78	1.90	1.92	0.02	0.06	3.90	0.34	1.38	2.64	0.69	0.29	0.29	#	2.24	3.30	2.66	0.75	0.29	0.29	8.20
380	730.75	0.90	1.02	0.12	0.06	2.10	0.17	0.75	0.98	0.40	0.29	0.34	#	1.07	1.77	1.10	0.46	0.29	0.34	3.93
381	731.90	1.80	1.96	0.16	0.18	4.10	0.06	0.34	0.40	0.98	0.86	0.57	#	1.86	2.30	0.56	1.16	0.86	0.57	4.72
382	733.04	5.20	6.34	1.14	0.12	12.80	0.06	0.86	4.65	1.72	0.23	0.00	#	5.26	7.20	5.79	1.84	0.23	0.00	18.25
383	734.04	1.45	1.64	0.19	0.12	3.40	0.06	0.34	2.12	0.92	0.75	0.23	#	1.51	1.98	2.31	1.04	0.75	0.23	5.81
384	734.72	2.25	2.46	0.21	0.18	5.10	0.11	5.68	4.19	0.98	0.40	0.23	#	2.36	8.14	4.40	1.16	0.40	0.23	14.91
385	735.63	4.50	5.39	0.89	0.12	10.90	0.00	0.98	0.57	0.40	0.57	0.29	#	4.50	6.37	1.46	0.52	0.57	0.29	12.33
386	736.56	2.50	2.75	0.25	0.00	5.50	0.00	0.06	0.92	0.00	0.00	0.00	#	2.50	2.81	1.17	0.00	0.00	0.00	6.48
449	798.69	1.40	2.77	1.37	1.56	7.10	0.17	0.86	2.75	3.62	2.47	1.09	#	1.57	3.63	4.12	5.18	2.47	1.09	9.33
450	799.57	1.35	1.65	0.30	0.00	3.30	0.29	1.55	2.81	3.10	3.10	0.29	#	1.64	3.20	3.11	3.10	3.10	0.29	7.95
451	800.71	0.70	1.02	0.32	0.36	2.40	0.29	0.98	4.02	8.49	2.58	1.03	#	0.99	2.00	4.34	8.85	2.58	1.03	7.32
452	802.02	3.50	4.36	0.86	0.18	8.90	0.46	1.15	1.84	1.55	0.92	1.32	#	3.96	5.51	2.70	1.73	0.92	1.32	12.16
453	802.98	3.75	5.05	1.30	0.30	10.40	0.17	0.57	3.56	1.84	2.24	1.21	#	3.92	5.62	4.86	2.14	2.24	1.21	14.40
454	803.91	3.65	4.98	1.33	0.84	10.80	0.06	1.03	4.42	1.38	0.92	0.11	#	3.71	6.01	5.75	2.22	0.92	0.11	15.47
455	804.79	2.55	2.75	0.20	0.00	5.50	0.17	2.70	7.17	7.17	0.11	0.00	#	2.72	5.45	7.37	7.17	0.11	0.00	15.54
456	805.54	5.65	7.42	1.77	0.66	15.50	0.00	0.98	3.33	1.43	0.98	1.66	#	5.65	8.40	5.10	2.09	0.98	1.66	19.14

Summary of all SWH creation efforts:

Kansas City District Missouri River Construction Summary River Mile 498 to 0, Kansas City District				
Bank Notching				
	96 Bank notching areas			
	SWH acreage estimated :	384 to 576		
Dike Notching				
	830 Dike notching areas			
	SWH acreage estimated :	658 to 3689		
Revetment Lowering				
	176 Revetment notching areas			
	SWH acreage estimated :	160 to 534		
Chutes				
	SWH acreage estimated :	151 to 282		
Pilot Channel				
	SWH acreage estimated :	20 to 49		
All Construction Activities Total		1373 to 5130		